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# ACQUISITION RESEARCH PROGRAM
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## Two–Bin Kanban: Ordering Impact at Navy Medical Center San Diego

17 June 2016

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# ABSTRACT

One of the most important aspects of hospital administration is the medical consumable inventory process. The Navy Bureau of Medicine and Surgery (BUMED) hopes to improve the medical inventory process across the Navy Medicine enterprise with a new lean medical inventory system called two-bin Kanban. In 2014, BUMED implemented two-bin Kanban inventory systems in 22 Navy military treatment facilities (MTFs). This project analyzes the efficiency and effectiveness of the two-bin Kanban inventory system in three departments at Navy Medical Center San Diego (NMCSD).

In this evaluation, over 163,000 medical consumable transactions worth a net value of $1.6 million were analyzed across two years (2013 and 2015). Inventory ordering patterns, cost savings/avoidance, and cost per relative value unit (RVU) are a few analyses that were conducted to determine what impact, if any, two-bin Kanban had on the Gastroenterology, Urology, and Oral Maxillofacial Surgery (OMFS) departments at NMCSD. The data is statistically significant in 2015 when compared to 2013. Procurement order costs decreased and procurement order efficiency improved across all departments. However, given the nature of the observations and the existence of other process improvement efforts, this research is unable to confirm if the two-bin Kanban was the cause for the performance improvements.

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## ACKNOWLEDGMENTS

First and foremost, I have to give glory to God. Through him all things are possible. I am here because of my family's unwavering love and support. They give me strength to be my best self. God has blessed me with an amazing wife and three beautiful daughters. Jacquelene, you are my soul mate. Your love has guided me through many tough times. Many scary nights abroad were palatable because I knew what I was fighting for back home. I am excited to spend the rest of my life growing old and grey with you. Lily and Zoe, your fun-loving spirit and constant giggles make my days exciting, unpredictable, and memorable. Mom and Dad, I love you. Your relentless support in troubled times pushed me through many difficult situations in my life. Through this, I truly understood the meaning of unconditional love. I pray I can repay this debt onto my children. Josie and Alex, I thank you, too. Your support over the last decade and a half has culminated to this moment.

I am also grateful to be in a position to learn from the world's best educators at the finest institution on the globe. I am grateful to be a part of an organization such as the Navy, through which I strive to live by the principles of honor, courage, and commitment. I am blessed to be a part of Navy Medicine, where taking care of our nation's heroes and family members takes center stage. I pray I can pass on all the blessings I have been given by so many people in my life.

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## ABOUT THE AUTHOR

**Lieutenant Audrey Carter** enlisted in the Navy in 1999 as a Hospital Corpsman. During his first five years, Lieutenant Carter was a Fleet Marine Force Corpsman assigned to 1st Marine Division, 7th Marine Regiment in 29 Palms, California. He made multiple operational deployments supporting the war on terror. In 2005, while assigned to Bethesda Naval Hospital as a Physical Therapy Technician, Lieutenant Carter earned his Bachelors of Science from the Southern Illinois University satellite campus. He was subsequently selected to attend Texas State University under the Health Service Collegiate Program, where he earned a Master's Degree in Health Administration and was commissioned as a Lieutenant Junior Grade. During his first tour as a Medical Service Corps Officer, Lieutenant Carter was a Department Head of Business Operations at Naval Hospital Oak Harbor aboard Naval Air Station Whidbey Island, Washington. While stationed at Oak Harbor, Lieutenant Carter deployed to Afghanistan as the Chief of the Afghan National Army Internal Control Team. Lieutenant Carter then took a job as the Director of Resources and Head of Material Management for 3d Dental Battalion/U.S. Naval Dental Center, Okinawa Japan from 2011 – 2014. Lieutenant Carter recently graduated from the Naval Postgraduate School earning a Master of Business Administration degree in Supply Chain Management. Lieutenant Hill's personal awards include the Defense Meritorious Service Medal, Navy and Marine Corps Commendation Medal, Navy and Marine Corps Achievement Medal (three awards) as well as multiple unit, combat, and service awards. He is married to the former Jacquelene Ceralde and has three children.

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# TABLE OF CONTENTS

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# LIST OF FIGURES

# LIST OF TABLES

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# LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| AHLTA | Armed Forces Health Longitudinal Technology Application |
| ARMDEC | U. S. Army Aviation and Missile Research Development and Engineering Center |
| BUMED | Navy Bureau of Medicine and Surgery |
| CMS | Centers for Medicare and Medicaid Services |
| CHCS | Composite Healthcare System |
| CPT | current procedural terminology codes |
| DMLSS | Defense Medical Logistics Standard Support |
| DOD | Department of Defense |
| FIFO | first in, first out |
| HCPCS | healthcare common procedure coding system |
| HMS | Navy Hospital Corpsmen |
| ID | identification |
| JHUAPL | Johns Hopkins University Applied Physics Laboratory |
| JIT | just-in-time |
| MHS | military health system |
| MTF | military treatment facility |
| NHCP | Naval Hospital Camp Pendleton |
| NMCSD | Navy Medical Center San Diego |
| OMFS | Oral Maxillofacial Surgery |
| RFID | radio frequency identification |
| RVU | relative value unit |
| SAIC | Science Applications International Corporation |
| TPS | Toyota Production System |
| WRNMMC | Walter Reed National Military Medical Center |

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# EXECUTIVE SUMMARY


In 2014, BUMED implemented a two-bin Kanban inventory system at NMCSD. The two-bin Kanban system is a centralized inventory management approach aimed at optimizing product availability while trying to minimize the cost to the supply chain. In a two-bin Kanban system, consumable items are placed in two bins with an equal amount of product in each bin. The medical staff pulls product from the front bin until it is empty. The staff can then pull from the second bin. Supply technicians check all Kanban bins in every department periodically throughout the week. If a bin is empty, the supply technician will reorder the entire contents of that bin, and replenishment from a centralized inventory in the medical warehouse soon follows.

The bins should assist in establishing the department demand at the item level. This will assist in adjusting the bin size and frequency of order requirements. With improved inventory levels and frequency of orders, it is assumed spoilage will decrease, inventory needs will decrease, and inventory stockpiling will decrease. Through these effects, it is assumed the two-bin Kanban inventory system will reduce costs. It is the aim of this research to analyze the cost effects of this system.

The findings are supported by 24 months of data, consisting of 163,000 line items accounting for ~$1.6 million in inventory ordering costs across FY 2013 and FY 2015. Three departments, Gastroenterology, Urology, and OMFS, are reviewed. The data was divided into the before and after aggregates with the Kanban implementation being the separator of these aggregates for all departments under review.

The cost data is split into two tests: procurement order cost or “effectiveness,” and procurement cost per RVU or “efficiency.” The procurement order cost aggregates every department supply order transaction cost into a monthly sum. This monthly sum is the basis for analysis. A similar approach is conducted for the efficiency measure. In the efficiency measure, the monthly procurement order cost is divided by RVUs. This procurement order cost per RVU is the amount of money the department spends on supplies per RVU.

The data observed shows statistically significant evidence that both procurement order cost and procurement order cost per RVU decreased in 2015 after the two-bin Kanban implementation in 2014. In Table 1, a decrease in monthly medians for both procurement order costs and procurement cost per RVU is demonstrated. A summary of the P-values, which are subsequently all below the critical factor of .05, is given in Table 2. This means the costs in 2015 are lower the costs in 2013 for both the procurement order cost and procurement order cost per RVU.

Table 1. Summary findings of monthly medians

| | Procurement Cost | | Procurement Cost per RVU | |
|---|---|---|---|---|
| Department | Before | After | Before | After |
| Gastroenterology | $ 36,434.92 | $ 26,791.91 | $ 11.55 | $ 9.89 |
| Urology | $ 16,165.52 | $ 6,327.85 | $ 3.26 | $ 1.68 |
| OMFS | $ 29,924.32 | $ 16,749.29 | $ 23.81 | $ 9.99 |
| TOTAL | $ 94,122.00 | $ 53,359.00 | $ 10.15 | $ 5.93 |

Table 2. Wilcoxon P-value with an Alpha of .05

| | Procurement cost | Procurement cost per RVU |
|---|---|---|
| Gastroenterology | 0.0163 | 0.0470 |
| Urology | 0.0002 | 0.0007 |
| OMFS | 0.0105 | 0.0105 |
| TOTAL | 0.0009 | 0.0028 |

The differences in all of the costs when comparing 2013 to 2015 have a p-value below the critical threshold of .05. Based on this, the project can assert the decreases in costs are not attributed to randomness. The data does not suggest the cost reductions have been caused by the two-bin Kanban. This is determined because of two other factors: (1) order quantity inconsistencies at the Kanban item level; and (2) enterprise efforts in reducing purchase care (PC) procurements. The impact of these two factors could not be isolated in this research, which makes the determination of the procurement cost reduction not causative at this time.

# I. INTRODUCTION

## A. BACKGROUND

The fiscal year (FY) 2016 Department of Defense (DOD) budget request included $47.8 billion to support the military health system (MHS) (Office of the Under Secretary of Defense Chief Financial Officer, 2015). In 1990, the DOD Healthcare budget was 4% of the total DOD base budget. In 2015, this percentage had risen to 10% of the DOD base budget (Office of the Under Secretary of Defense Chief Financial Officer, 2015). This increase in health care requirements is alarming given that many of the 9.2 million MHS beneficiaries are aging and will require even more health care in the years to come.

The MHS has developed a strategic model called the Quadruple Aim that serves to improve the quality of care and decrease the cost of healthcare. The Quadruple Aim is the platform that aligns process improvement efforts for DOD MHS medical commands. One of the tenets of the Quadruple Aim is to responsibly manage the total cost of healthcare. This is done by “focusing on quality, eliminating waste, reducing unwarranted variation, and considering not just the cost of an individual healthcare activity, but the total cost of care over time” (Office of the Under Secretary of Defense Chief Financial Officer, 2015, p. 6-10)

In an effort to curb increasing healthcare costs through the strategic framework of the Quadruple Aim, the Navy Bureau of Medicine and Surgery (BUMED) is focusing on process improvements. One of BUMED’s solutions was the implementation of a two-bin Kanban inventory system across the Navy Medicine enterprise. In 2014, BUMED implemented two-bin Kanban inventory systems at 22 Navy military treatment facilities (MTFs).

## B. PROBLEM STATEMENT

There have been enterprise-wide concerns with the two-bin Kanban system implementation. Several logistical stakeholders question the value of the two-bin Kanban system. The implementation for two-bin Kanban was pushed from BUMED down to the

MTF level. The intent of this project is to analyze the value and effectiveness of the two-bin Kanban system at Naval Medical Center San Diego (NMCSD).

## C. KANBAN INVENTORY MANAGEMENT

The pioneer of the two-bin inventory management system was the supermarket. Food waste is a very high expense for many supermarkets. To mitigate food waste, the grocers would only order an item when it was near sellout. In the late 1940s, Toyota adopted this process. In Japan, where Toyota is headquartered, the term *Kanban* means “visual signal” or “card.” In the mid-1970s, Japan’s economy was sluggish due to the oil crisis in 1974. During this time, Toyota was still able to become Japan’s most profitable business. Many people attribute Toyota’s success to its manufacturing system called the Kanban method (Shingo, 1989). The premise behind the Toyota Kanban system was a stockless inventory. Toyota had three key differences in production when compared to Ford, one of their competitors: “(a) smaller lot sizes, (b) mixed-model production, and (c) continuous one piece flow operation from processing to final assembly” (Shingo, 1989, p. 92). Toyota utilized an actual card to aid in communication throughout the production process. The primary goal of Toyota’s Kanban system was to eliminate waste and decrease costs. Toyota focused on order-based demand vice forecasted demand, which resulted in smaller inventories (Shingo, 1989).

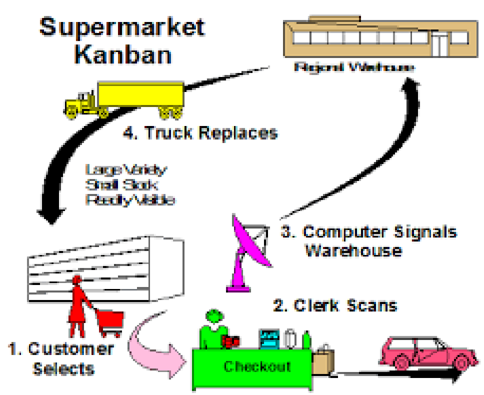



Figure 1. Kanban Flow in a Supermarket. Source: Stratego (2007).

One Kanban variation that the Healthcare industry has adopted includes the use of barcode readers to periodically scan for needed supply replenishment. In this system, two bins split the inventory stock quantities. When one bin is emptied, the entire contents of that bin are reordered via barcode scanner. The clinician who pulls the last items in the bin pulls that bin out of the shelving unit and places it on a pre-designated scanning area. Each bin has a reorder card attached to it. Supply technicians walk through the departmental supply rooms every day to scan for empty bins. The second bin has enough product to last until the first emptied bin is replenished.

Photo taken by the LT Audrey Carter on 23 March 2016 at NMCSD

Figure 2. Gastroenterology Kanban Shelving.

This inventory process potentially has many benefits. The streamlined system removes the need for trained departmental supply representatives, a constant struggle for every military hospital. Typically, Navy MTF staff must utilize untrained Navy Hospital Corpsmen (HMs) to be departmental supply representatives. The HMs typically remains in a department from six months to three years. During this time, the HMs also have other clinical duties and intermittent military deployments abroad, causing gapping concerns in the supply representative role. Turnover of personnel typically occur without notice. The

two-bin Kanban system reduces the need for a departmental supply representative. Centralized ordering also enables this Kanban system to decrease inventory ordering costs by reducing the amount of people placing orders. Departmental supply reps order manually in Defense Medical Logistics Support System (DMLSS) while the bar code scanner bulk orders with a simple connection between the scanner and a computer. Holding costs are also decreased with this just-in-time (JIT) inventory fulfillment based on actual demand. The requirement for a large warehouse is minimized with this system, and a smaller amount of product turns faster.

## D. THESIS OUTLINE

The first chapter reviewed the thesis problem and provided background information. The second chapter is a review of applicable healthcare inventory and logistics literature. The third chapter discusses the inventory ordering data that is utilized in analyzing the effectiveness of the two-bin inventory system. The fourth chapter offers an analysis of the data. In the last chapter, a discussion on the analysis is conducted, including conclusions and recommendation for follow-on research.

# II. LITERATURE REVIEW

The focus on process improvement began in the automotive industry with Ford Motor Company and Toyota (Lean Enterprise Institute, n.d.). Mass production of the Ford Model T was the first attempt at lean production in our modern times (Lean Enterprise Institute, n.d.). The basis of the production line for the Ford Model T was about "machine-produced interchangeable parts and orderly flow of those parts first to subassembly, then to final assembly" (Sorensen, Williamson, & Lewis, 2014, p. 115). There were indeed other industries that adopted machine-produced interchangeable parts prior to Ford. There were also other industries that had some form of orderly flow of parts (Sorensen, Williamson, & Lewis, 2014). Ford was the first to arrange the work site where the product flowed from one worker to the next. Each worker's task was undertaken at just the right time until the vehicle was complete (Sorensen, Williamson, & Lewis, 2014).

The Toyota Production System (TPS) was slightly different from that of Ford's production of the Model T. TPS focuses on smaller lot sized production via order based demand (Shingo, 1989). This is known as a just in time (JIT) production system. In this system, the production process is driven from actual demand. This process inherently reduces waste, which is a premise of the TPS. One of the tools the TPS utilized was the Kanban system. Kanban was originally implemented to create standard operating procedures, give directions, and reduce unnecessary work (Lu, 1989). Kanban outcomes include (a) elimination of over production, (b) priority production identification, and (c) improved material control (Lu, 1989).

The lean production practices as demonstrated by Ford and Toyota have become commonplace in many different business sectors in today's competitive business economy. The health care industry, however, has been sluggish to implement these proven lean production practices (McKone-Sweet, Hamilton, & Willis, 2005). Many years ago, Navy medicine focused on healthcare quality, access, and cost. This three-pronged effort is known as the Iron Triangle. The primary mechanism to improve these three areas was a focus on the healthcare system as a whole or on clinical processes.

Barriers to the lean practices in health care include poor management support, poorly aligned incentives, poor data analytics, lack of supply chain education, and weak purchasing agreements with vendors (McKone-Sweet, Hamilton, & Willis, 2005). The delayed implementation is noteworthy given approximately 40% of a hospital's expenditures are attributed to the supply chain (McKone-Sweet, Hamilton, & Willis, 2005).

Lean management practices began to emerge in hospitals between 1980 and 1990 (Battini, Rafele, & Persona, 2008). According to a study conducted by Battini, Rafele & Persona, two hospitals in Italy, Padua City and Turin changed their conventional inventory practices to a Kanban inventory system. The conventional inventory practice consisted of large warehouse centralized ordering and smaller, often disorganized departmental supply spaces. In the new Kanban system, a movable card was placed on a double-sided basket into which the medical consumables were divided equally for standardized reordering and replenishment. The goal of the administration was to keep the process very simple. In both hospitals, the implementation of the Kanban system resulted in positive outcomes. Medical supply order variation decreased by up to 80%. The supply facility footprint was reduced and order frequency was standardized. This ultimately resulted in a decrease in expiring products and better organized purchasing (Battini, Rafele, & Persona, 2008).

A 2010 report from the *New York Times* detailed Kanban implementation at Seattle Children's Hospital. The nursing staff consistently stockpiled medical supplies. Stockpiling supplies is called the "bull whip effect" and it is a wasteful impact of a poorly managed supply system. The medical supply system was poorly managed and resulted in staff members creating small supply stockpiles throughout the hospital. It would not be uncommon to find catheters in closets or surgical dressings in a patient's dresser drawers (Weed, 2010). This practice became critical for the administration to rectify, since healthcare providers need life-saving medical supplies at a moment's notice in intensive care environments such as this hospital. To remedy the situation, Seattle Children's Hospital implemented a two-bin Kanban system (Weed, 2010). In this system, medical supplies are divided into two bins equally. As one bin is emptied, a staff member pulls a

card off the front of the bin and places it in a reorder box. The contents of the second bin are then utilized until the first bin is replenished by the supply department staff. The supply department staff makes daily rounds to all of the hospital's supply storage rooms. This inventory system is similar to TPS and is very common in manufacturing today. With this new system, Seattle Children's Hospital was able to reduce its cost per patient by 3.7% for a savings of $23 million (Weed, 2010).

In 2014, Concord Hospital in Concord, NH, completed the implementation of a two-bin Kanban system enabled with radio frequency identification (RFID). The system implementation was in response to the regional center's initiative to streamline logistical practices among its 38 storage areas and increase the efficiency of its supply chain. This system is similar to the Kanban system in place at NMCSD. The departmental storage areas were outfitted with a two-bin supply storage system, where supplies are equally split into two bins. Each bin has a passive RFID tag that communicates with the hospital inventory system. As the bin is emptied, a staff member puts the tag on a board to trigger a reorder. A trigger is received in the warehouse that the bin needs to be replenished. The benefits of this implementation include a 13% reduction in inventory levels and the recovery of 24% of floor space (Polka, 2014).

The Walter Reed National Military Medical Center (WRNMMC) in Bethesda, MD, was created through a merger of the Bethesda Naval Hospital and the Walter Reed Army Medical Center. This was brought about by the base realignment and closure commission (BRAC) report in 2005. Combining the Navy and Army inventory processes was a concern for Navy Medicine leadership. The status of the supply chain, especially, had some inherent concerns:

> (1) supply replenishment was handled by a rotating and temporary staff. (2) A daily inventory of each item was needed. Due to the effort required with counting, cart techs are simply eye-balling the bin locations leading to inventory accuracy concerns. (3) Replenishment quantity varies drastically on usage, creating opportunity for replenishment error. (4) Inventory expiration was not managed to eliminate the frequency of expired items. (Olson, 2014,p. 1)

As a result of these concerns, an RFID-enabled two-bin Kanban inventory management system was implemented in 2011. A follow-on study was conducted in 2014 to ascertain the effectiveness of this inventory system on controlling ordering costs and providing other organizational benefits. The study was inconclusive in determining if any inventory benefit had occurred, but it did determine that organizational benefits had been obtained (Olson, 2014).

This paper analyzes the effectiveness of the lean healthcare concept of two-bin Kanban in inventory management at the NMCSD. A similar analytical analysis was undertaken in 2014 at WRNMMC in examination of that facility's use of RFID-enabled two-bin Kanban. The analysis focuses on the ordering efficiency improvements realized through the two-bin Kanban system implemented by the Bureau of Medicine and Surgery (BUMED).

# III. DATA

Two data sets utilized for this graduate project were obtained from NMCSD's DMLSS servers via the business objects software at the hospital. One report in business objects was titled "All Cust Order Total Report Ver2." The data was delivered in text file format via the U. S. Army Aviation and Missile Research Development and Engineering Center (ARMDEC) safe file exchange. The text files were converted into a Microsoft Excel database format for data manipulation using pivot tables and pivot charts. This data set contains all ordering activity for the NMCSD bulk ordering codes. For this data set, each row contained Customer Organization Id : Name (DMLSS customer responsible for the order), Order Date (specific day the order was placed), Item ID & Description (generic item name), UOP code (classifying unit of purchase), quantity (how many ordered), UOP Price (price per unit), Order Price (total order cost, SOS Code (Source of Supply or what type of vendor), SOS Name (specific name of the source of supply). This data displayed individual item transactions for the entire time periods under review, which is covered more thoroughly later in this chapter. This can be seen in Table 1.

Table 1. Example of Data Set from All Cust Order Total Report Ver2.

| Customer Name | Order date | Item ID & Description | UOP | Quantity | UOP Price | SOS Code |
|---|---|---|---|---|---|---|
| UROLOGY CLN | 10/15/2012 | CYSTO/UROLOGY 21 | EA | 24 | $2.20 | MATERIAL MANAGEMENT |
| UROLOGY CLN | 10/15/2012 | TAPE,SILK,2 | RO | 4 | $1.09 | MATERIAL MANAGEMENT |
| UROLOGY CLN | 10/17/2012 | 60CC SYRINGE LUER LOK | EA | 20 | $0.41 | MATERIAL MANAGEMENT |
| UROLOGY CLN | 10/17/2012 | EMESIS,PLASTIC | EA | 3 | $0.14 | MATERIAL MANAGEMENT |
| UROLOGY CLN | 10/17/2012 | GLOVE XAM NLNP NS SM | BX | 1 | $3.49 | MATERIAL MANAGEMENT |
| UROLOGY CLN | 10/17/2012 | GLOVE XAM NLNP NS LG | BX | 5 | $3.49 | MATERIAL MANAGEMENT |

The data report, as depicted in Table 1, included several data elements not needed for analysis that were subsequently discarded to streamline the pivot table function and to decrease the file size. These data elements include order document number, call number, items due in, items canceled, PC Total, and ordering official. Several descriptive data elements were added to this data set to aid in analysis. These include fiscal year (FY), month (to aid in order timeline analysis), and order type (as figured from the SOPS code

given in the data set). All of the data elements either directly supported the analytics of this study, or assisted in filtering the data for improved reporting/comparison.

A second DMLSS data report titled "customer usage reports" was also collected from the NMCSD DMLSS SA (see Table 2). Many of the data elements from the customer usage report matched that of the All Cust Order Total Report Ver2. The customer ID in the customer usage report begins with XX. This code was modified in the data set to match the customer coding in the All Cust Order Total Report Ver2. The date of receipt header in the customer usage report matched the order date header in the All Cust Order Total Report Ver2. The customer usage report also contained many data elements not needed for this project and these were subsequently removed from the data set in order to create a smooth data set for aggregation. These data elements include document order, User ID, and call number.

Table 2. Example of Data Set from the Customer Usage Report.

| Date of Receipt | Item Description | SOS Code | Customer Id | UP Code | Receipt Quantity | Unit of Purchase Price |
|---|---|---|---|---|---|---|
| 10/2/2014 | 60CC SYRINGE LUER LOK | R11 | XXIA09 | EA | 15 | $0.33 |
| 10/2/2014 | MULTISTIX 10 SG | R11 | XXIA09 | BT | 2 | $38.93 |
| 10/2/2014 | BAG DRAIN URINE LEG 19OZ ANTI-REFLUX V | R11 | XXIA09 | EA | 6 | $3.61 |
| 10/2/2014 | GLOVE, SURGICAL STERILE SYNTHETIC POW | R11 | XXIA09 | EA | 50 | $1.78 |

A complete ordering history can be observed by combing both of these reports. The All Cust Order Total Report Ver2 displays all orders placed in DMLSS directly with external suppliers. The customer usage report displays all orders placed in DMLSS that was sourced from an internal supplier (material management).The data set contained ~163,000 line items accounting for ~$1.6 million in inventory ordering costs across two fiscal years.

## A. DEFENSE MEDICAL LOGISTICS STANDARD SUPPORT

DMLSS is an automated information system that implements a medical logistics platform at DOD medical treatment facilities (MTFs) (Defense Health Agency, 2016).

The system manages four functional areas: (a) material management, (b) facility management, (c) equipment and technology, and (d) wholesale (Global Security, n.d.).

### 1. Defense Medical Logistics Standard Support Limitations

The customer identifications (IDs) established in DMLSS do not necessarily match customer IDs in other systems. For example, the Gastroenterology Department's customer ID in the usage report is XAGA09. In the second report, the customer ID for the same department is BAGA01. When combining the data, these discrepancies were manually smoothed.

Recommended stocking levels, or Par values, are available via DMLSS at the item level. However, this information is only a snapshot of the day the report is generated. There is no way for DMLSS to retroactively retrieve PAR values of inventory. One of the known outcomes of inventory improvement projects is a one-time reduction in inventory stocking requirements. This conclusion could not be verified through DMLSS because it was not practical to keep a daily snapshot of inventory levels over an extended period of time.

DMLSS is not linked to clinical workload data. There may have been an increase or decrease in clinical capabilities or services conducted over the time span of data collection. This may have impacted inventory ordering. The impact on workload is not taken into account for this analysis.

DMLSS does not smooth or average out pricing over time. The data reports obtained display the unit price per item as it was during the time of order. As such, some items may have price changes from the vendor. When this occurs, and average price is determined and used in both data sets (2013 and 2015). For example, a 2 x 8 green log book cost $2.94 on December 12, 2012. This same book cost $3.76 on June 30, 2015. These two costs were averaged to $3.35 in both the pretest (2013 data set) and posttest (2015 data set) analysis to avoid having the findings influenced by price changes.

DMLSS does not track shipping timelines. This would be very beneficial when looking to establish appropriate safety stocks, re-order points, and economic order

quantities. Given this limitation, this project does not address any of these inventory topics.

In this project, one aspect of the analyses tracked a few regularly ordered items. Ordering patterns were then analyzed for these specific items over time in both data sets. Some of the regularly ordered items in the 2013 data set may have been replaced with similar or substitute items in the 2015 data set. Given the size of the data set, there is no way to know which, if any, of these items are substitutes. There is no functionality in DMLSS to track substitute or similar items. As such, another aspect of this analysis specifically tracked items that appear in both data sets with the same item description.

## B. ARMED FORCES HEALTH LONGITUDINAL TECHNOLOGY APPLICATION

Armed forces health longitudinal technology application (AHLTA) is the DOD electronic health record. Patient encounters, medical history, lab results, x-ray images, and so forth are all documented in AHLTA. AHLTA is the "clinical engine" and it also provides the basis for medical coding information (Defense Health Agency, n.d.). Medical coding is how physician and ancillary services are documented for insurance and financial collection purposes. When a physician enters the patient encounter into

## C. COMPOSITE HEALTHCARE SYSTEM

In 1988, a $1.02 billion contract was awarded to Science Applications International Corporation (Beyster, 2007) for the development of a medical informatics system for the DOD. SAIC developed the composite healthcare system (CHCS) as the DOD's medical informatics system. CHCS is utilized for a myriad of medical administration and clinical functions. CHCS is divided into multiple software modules (Open Health News, n.d.)

In this study, the important module is the ADM. The ADM module in CHCS contains clinical RVU data. The RVU data is pulled into CHCS from system synchronization with AHLTA. The RVU data is then synced into a DOD data repository

titled the M2 Data Mart. M2 Data Mart is then queried via Business Objects software for workload data analysis (Hourigan, personal communication, 22 March 2016)

## D. RELATIVE VALUE UNIT

The RVU has become the primary workload measurement metric for the collective healthcare industry for productivity. The Centers for Medicare and Medicaid Services (CMS) has a billing matrix to determine how much should be paid for over 9,000 physician services. CMS hinges its medical payment based on the RVU. The RVU is reflective of the level of resources required for the services provided. These resources include: (a) the physicians' amount of work, (b) the physicians' expenses, (c) and the cost of liability insurance. In determining the exact amount of money to be paid for services based off a RVU, a dollar conversion factor is used in conjunction with the RVU valuation (Centers for Medicare and Medicaid Services, 2016).

Table 3 displays a breakdown of physician services and RVUs. Each service has three components that earn RVUs. These components are summed for a total RVU per service provided. This RVU value for the specific service is universal for the healthcare industry. Medicare estimates the amount of physician work, expenses, and liability insurance cost when allocating the RVU valuation. Consideration is given to time to perform a procedure, technical skill and effort to perform a procedure/service, judgment, and stress performing the procedure. Practice expense RVUs is the estimated overhead the physician incurs to provide a specific procedure. This includes administrative labor and facility, consumable, and equipment expenses. RVUs for professional liability insurance are estimated to cover the cost the physician pays for of malpractice insurance.

Table 3. Example Breakout RVUs for Selected Services, 2014. Source: Centers for Medicare and Medicaid Services, 2016.

| Service | Total | Physician Work | Practice Expense | Professional Liability Insurance |
|---|---|---|---|---|
| Intermediate Office Visit | 3.01 | 1.5 | 1.41 | 0.1 |
| Diagnostic Colonoscopy | 11.03 | 3.69 | 6.78 | 0.56 |
| Total Hip Replacement | 38.94 | 20.72 | 14.32 | 3.9 |

For this study, the dollar conversion factor and the RVU breakdown specifics are not needed. This project only utilizes the total RVU trended over a period of time for each department under review.

A second data set came from data retrieval via business objects software through M2 Data Mart. This data set includes total monthly healthcare provider RVUs or workload data, which can be seen in Table 4. This report was pulled by a BUMED analytics staffer into Microsoft Excel for data aggregation and analysis. The data elements include total RVUs (workload data), FY (fiscal year), FM (fiscal month), Tmt DMIS IS Name (hospital name), MEPRS4 Code (department identification code), and MEPRRS4 Code Description (department name).

Table 4. Example of CHCS RVU Data Set.

| Total RVU | FY | FM | Tmt DMIS ID Name | MEPRS4 Code | MEPRS4 Code Description |
|---|---|---|---|---|---|
| 773.87 | 2015 | 8 | NMC SAN DIEGO | ABDA | NEUROSURGERY |
| 5706.4 | 2015 | 6 | NMC SAN DIEGO | ACBA | OBSTETRICS |
| 5880.75 | 2015 | 7 | NMC SAN DIEGO | ACBA | OBSTETRICS |
| 4630.89 | 2013 | 11 | NMC SAN DIEGO | ACBA | OBSTETRICS |

### 1. RVU Limitations

There has been some criticism of the RVU as the primary workload measure. Assigning the appropriate level of RVU valuation for primary care appointments is not easily quantified for the CMS. A stark contrast can be made when comparing a medical procedure. This is because the classification of medical services is lacking, despite CMS' best effort to keep a comprehensive list of medical services up to date. CMS struggles to keep pace with RVU policy revision given the speed with which medical technology and medical education are being pushed into the health care industry (Newton, 2002). There are several limitations that need to be considered when RVUs are utilized in analysis.

#### *a. Rapid Changes in Healthcare*

Briefly detailed earlier, CMS struggles to keep the RVU valuation current. Since the inception of the RVU, much has changed in terms of medical technology and medical

education. The prior assumptions in assigning the RVU valuation may no longer be accurate. Inaccuracies could occur for the following: (a) less expensive medical procedures that are assumed to be more expensive and (b) increased medical equipment cost due to the change in the standard of care.

#### *b. Downtime*

Downtime is defined as the amount of time the physician needs to be available for patient care. This could be to assist in coordinating the transition of a patient, or being on-call in case of in case medical services are needed. Downtime is not included in the RVU valuation. Some services lend themselves to higher levels of downtime than others, which could inaccurately account for the amount of time required for specific services. “Medicare rules allow crediting of time for coordination of care spent in the presence of the patient but do not allow billing for time spent talking to other physicians, home health nurses, or staff at nursing homes” (Johnson, 2002, p. 175).

#### *c. Complexity Patients, Provider Expertise, and Quality of Care*

Certain populations of patients require a higher level of expertise of care; RVUs do not accurately measure complex patient encounters. For example, a chronically ill 90-year-old male with prostate cancer and rheumatoid arthritis comes to see his provider because he has the flu. The RVU assigned for this encounter would mirror the same encounter as for a 21-year-old male in pristine health condition, though the level of care required is much lower with the healthy male. The expertise of the physician, though very important for accurately treat a complex patient, is not accounted for when assigning weight to the RVU. RVU also do not consider the expertise of the provider offering that care. Lastly, quality of care is not considered in RVU valuation. Poor quality could lead to more expensive follow-up care. Despite this, the RVU valuation does not consider quality of care. The RVU only considers the service or procedure completed. RVUs do not reflect results or patient satisfaction; they only reflect the work that was completed.

## E. STUDY PERIOD

The two-bin Kanban system was implemented throughout FY 2014. The study periods are 12 months prior to implementation and 12 months after implementation. Given that the Kanban system was implemented in FY 2014, the study periods are FY 2013 (October 1, 2012–September 30, 2013) and FY 2015 (October 1, 2014–September 30, 2015). It is assumed the Kanban inventory system operated at a steady state in FY 2015.

# IV. DATA ANALYSIS

This chapter examines how the data was aggregated and what approaches were used to evaluate the two-bin Kanban system, and offers an analysis of the data. A discussion of the data preparation is offered. An evaluation of the cost analysis and how this has been defined into two distinct approaches is detailed. This report analyzes procurement cost and procurement cost efficiency. *Procurement cost* is defined as the unit cost to procure the item as defined by the vendor and does not include any administrative, salary, or holding costs. *Procurement cost efficiency* is defined as the ratio of RVU over procurement cost or "cost per RVU." Once these approaches have been reviewed, a summary of the results is presented. This chapter includes a presentation of the data, followed by a discussion.

## A. DATA PREPARATION

The data has four different organizing issues that must be addressed prior to aggregation. First, there were three distinct data sets that needed to be merged for a comprehensive review to be obtained. These data sets were described in Chapter III. These include the all Cust Order Total Report Ver2, the customer usage report, and the CHCS RVU Data Set. The two reports from DMLSS had the same data elements required for analysis, though the order of the columns and some of the column header titles were slightly different. These two data sets were merged with the columns of data rearranged to ensure the same columns were consistent for the entire data set. This can be seen in Table 5.

Table 5. Sample of Two Different DMLSS Data Sets Pre-merger.

| Item Description | SOS Code | Customer Id | UP Code | Receipt Quantity | Unit of Purchase Price | Date of Receipt |
|---|---|---|---|---|---|---|
| 60CC SYRINGE LUER LOK | R11 | XXIA09 | EA | 15 | $0.33 | 10/5/2012 |
| MULTISTIX 10 SG | R11 | XXIA09 | BT | 2 | $38.93 | 11/2/2012 |
| BAG DRAIN URINE LEG 19OZ ANTI-REFLUX VAL | R11 | XXIA09 | EA | 6 | $3.61 | 10/3/2012 |
| GLOVE, SURGICAL STERILE SYNTHETIC POWDE | R11 | XXIA09 | EA | 50 | $1.78 | 10/12/2012 |
| | | | | | | |
| | | | | | | |
| **Customer Name** | **Order date** | **Description** | **UOP Code** | **Quantity** | **UOP Price** | **SOS Code** |
| UROLOGY CLN | 10/4/2012 | ENDOPYELOPLASTY STENT 7/14 24 CM | EA | 1 | $204.00 | ALH |
| UROLOGY CLN | 10/4/2012 | ENDOPYELOTOMY STENT 7/14 26CM | EA | 1 | $204.00 | ALH |
| UROLOGY CLN | 10/9/2012 | GUIDEWIRE UROLOGICAL STRAIGHT DOUBLE FIX | BX | 12 | $225.24 | LSY |
| UROLOGY CLN | 10/15/2012 | SHEATH URETERAL ACCESS SINGLE LUMEN 12/1 | EA | 3 | $499.99 | NTB |

The matching colors in both sets of data represent matching data elements, despite potential variability among data headers.

The block RVU data set was organized with a pivot table in Microsoft Excel and merged into an aggregated monthly departmental procurement cost data set from DMLSS in Table 6. An efficiency ratio was then created with monthly procurement cost data divided by monthly RVU data. This efficiency header is titled “Cost per RVU.” Table 7 shows a sample of this aggregated data set that was utilized in the analysis.

Table 6. Sample of Two Different DMLSS Data Sets Post-merger.

| Item Description | SOS Code | Customer Id | UP Code | Receipt Quantity | Unit of Purchase Price | Order Date |
|---|---|---|---|---|---|---|
| 60CC SYRINGE LUER LOK | R11 | UROLOGY CLN | EA | 15 | $0.33 | 10/5/2012 |
| MULTISTIX 10 SG | R11 | UROLOGY CLN | BT | 2 | $38.93 | 11/2/2012 |
| BAG DRAIN URINE LEG 19OZ ANTI-REFLUX VAL | R11 | UROLOGY CLN | EA | 6 | $3.61 | 10/3/2012 |
| GLOVE, SURGICAL STERILE SYNTHETIC POWDE | R11 | UROLOGY CLN | EA | 50 | $1.78 | 10/12/2012 |
| ENDOPYELOPLASTY STENT 7/14 24 CM | ALH | UROLOGY CLN | EA | 1 | $204.00 | 10/4/2012 |
| ENDOPYELOTOMY STENT 7/14 26CM | ALH | UROLOGY CLN | EA | 1 | $204.00 | 10/4/2012 |
| GUIDEWIRE UROLOGICAL STRAIGHT DOUBLE FIX | LSY | UROLOGY CLN | BX | 12 | $225.24 | 10/9/2012 |
| SHEATH URETERAL ACCESS SINGLE LUMEN 12/1 | NTB | UROLOGY CLN | EA | 3 | $499.99 | 10/15/2012 |

The columns have been realigned and the headers have been remanded to provide one block set of data for aggregation.

Table 7. Sample of DMLSS and RVU Data Aggregated into a Monthly Block Set.

| Customer Organization Id : Name | FY | Month | Cost | RVUs | Cost per RVU |
|---|---|---|---|---|---|
| BBIA01 : UROLOGY CLN | 2013 | October | $ 15,393 | 4,618 | 3.33 |
| | | November | $ 23,522 | 4,542 | 5.18 |
| | | December | $ 34,396 | 4,019 | 8.56 |
| | | January | $ 30,808 | 4,771 | 6.46 |

The second organizing issue was the addition of descriptive data elements into the aggregated block data depicted in Table 8.

Table 8. Sample Aggregated DMLSS Block Data Set with Data Descriptors Added for Aggregation.

| Customer Name | Month | Fiscal Year | Order date | Item ID & Description | UOP | Quantity | UOP Price | Order Price | SOS Code | Purchase Method |
|---|---|---|---|---|---|---|---|---|---|---|
| UROLOGY | October | 2013 | 10/15/2012 | CYSTO/UROLOGY 21 | EA | 24 | $2.20 | $52.80 | LRF | Purchase Card |
| UROLOGY | October | 2013 | 10/15/2012 | TAPE,SILK,2 | RO | 4 | $1.09 | $4.36 | ECA | ECAT |
| UROLOGY | October | 2013 | 10/17/2012 | 60CC SYRINGE LUER LOK | EA | 20 | $0.41 | $8.20 | MM | MM |
| UROLOGY | October | 2013 | 10/17/2012 | EMESIS,PLASTIC | EA | 3 | $0.14 | $0.42 | MM | MM |
| UROLOGY | October | 2013 | 10/17/2012 | GLOVE XAM NLNP NS SM | BX | 1 | $3.49 | $3.49 | MM | MM |
| UROLOGY | October | 2013 | 10/17/2012 | GLOVE XAM NLNP NS LG | BX | 5 | $3.49 | $17.45 | MM | MM |

The added data descriptors are circled in blue.

These descriptive elements include fiscal year, month, order total, and purchase method. Reference tables in Microsoft Excel were created and the VLOOKUP function was utilized in three of the four new elements to label the line items. The fiscal year and month line items were referenced to the order date element already present. The purchase method element was referenced by the SOS code definitions per the NMCSD DMLSS SA. The order total data element was discovered by multiplying the order quantity by the unit purchase price.

The third organizing issue was the merger of multiple sub-departmental customers in both the DMLSS and CHCS data sets. For example, in the CHCS data set for the urology department, there are two customer codes—DFBA12: UROLOGY MOR (surgical unit) and BBIA01: UROLOGY CLN (outpatient unit). These constitute the outpatient clinic where specialty appointments, preoperative, and postoperative appointments are held and the surgical clinic where surgery occurs. Each of these clinics orders supplies in DMLSS. In this study, the summation of these orders was consolidated into one data set and the DMLSS ordering customer codes were combined. The same procedure was conducted for the CHCS RVU data. Urology has an outpatient clinic that generates RVUs classified under BBIA and has an ambulatory procedural unit generating RVUs titled BBI5. The CHCS RVU sample data set is depicted in Table 9. Combining the DMLSS procurement cost data and the CHCS workload data ensures the analysis

accurately depicts the procurement cost and procurement efficiency among the three departments under review.

Table 9. Sample of CHCS RVU Department Classification Variation Pre-Data Reorganization.

| Total RVU | FY | FM | Tmt DMIS ID Name | MEPRS4 Code | MEPRS4 Code Description |
|---|---|---|---|---|---|
| 698.02 | 2013 | 1 | NMC SAN DIEGO | BBI5 | UROLOGY CLINIC APV |
| 3055.98 | 2013 | 1 | NMC SAN DIEGO | BBIA | UROLOGY CLINIC |

In this specific case, BBI5 and BBIA would be consolidated for a new total RVU of 3,754 RVUs in October of 2012 (or FY 2013, FM 1) for the urology clinic.

Lastly, in an attempt to display the effects of the Kanban system's characteristics, departmental procurement ordering cost, orders placed, quantities ordered, and RVUs earned were divided into monthly and/or annual bins both before and after the Kanban implementation. This organization allows clear pre- and post-analysis to occur.

## B. AGGREGATED DATA

According to Kabacoff, "when you aggregate data, you replace groups of observations with summary statistics based on those observations (Kabacoff, 2011, p. 112). Replacing the groups of observations with summary statistics allows the analyst to structure the data to his or her liking. In this project, much of the data was put into a block format with like rows and like columns. Queries that were regularly used include monthly costs, cost type, and monthly workload, across several dimensions.

Purchase data is often held in a file containing one record per purchase. To better analyze this at the customer or item level, the data must be restructured so that multiple transactions are lumped into a larger aggregate. This paves the way for summary statistics into the shape of that data. It is often useful to have purchase data arranged so that each field represents a particular customer or product (Goodies, 2008).

### 1. Annual Procurement Order Cost and Quantity

In this section, the procurement order cost is divided into annual groupings. Annual data supports decisions in growth projections for management, and developing

and managing a business plan (Keolanui, n.d.). Annual data can also display cost and demand trends when assessing the impact of a new inventory strategy (Keolanui, n.d.). It is important to acknowledge potential impacts from other factors on the annual data displayed. These other factors include, but are not limited to: (a) raw material availability, (b) deployment schedules, (c) process improvements in procurement or inventory strategies, (d) population health, (e) competition, (f) growth, and new product lines (Keolanui, n.d).

In Figure 3, procurement cost data is seen in both FY 2013 and FY 2015 in all three departments under review. Gastroenterology spent $429,847 in 2013 and $309,850 in 2015. Urology spent $202,597 in 2013 and $79,155 in 2015, and Oral Maxillofacial Surgery spent $423,368 in 2013 and $227, 500 in 2015. A decrease in annual procurement costs can be seen for all three departments.

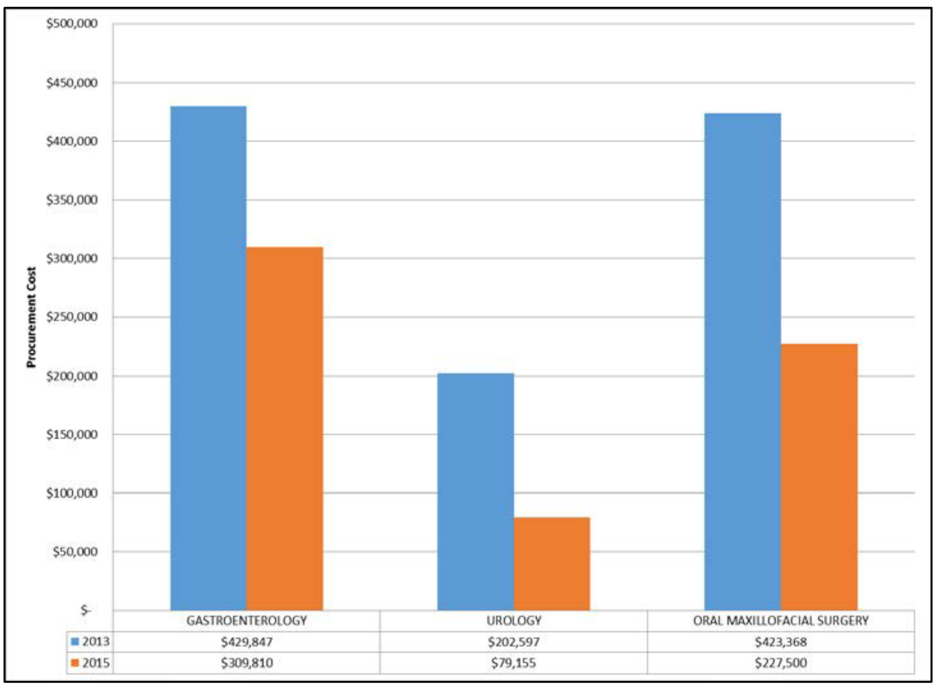



Figure 3. Annual Procurement Cost by Customer.

Quantity must also be considered when looking at the change of ordering over time. Total procurement cost is the primary concern to most managers. A single point of

focus does not contain enough information to draw any critical analysis. As such, this study also looks at the amount of orders placed. Gastroenterology placed 2,667 orders in 2013 and 2,734 orders in 2015. Urology placed 2,825 orders in 2013 and 2,779 orders in 2015. Oral Maxillofacial Surgery placed 2,719 orders in 2013 and 2,588 orders in 2015. These numbers are depicted in Figure 4. It is interesting to note that while the total procurement cost for Gastroenterology decreased from $429,847 in 2013 to $309,850 in 2015, the amount of orders placed increased from 2,667 in 2013 to 2,734 in 2015. It must be assumed that the price per order has decreased based off these data points. The other two departments posted a decrease in order quantity from 2013 to 2015. The decrease in the amount orders was not as drastic as the decrease in procurement cost in all customers. This resulted in a lower cost per order for all customers.

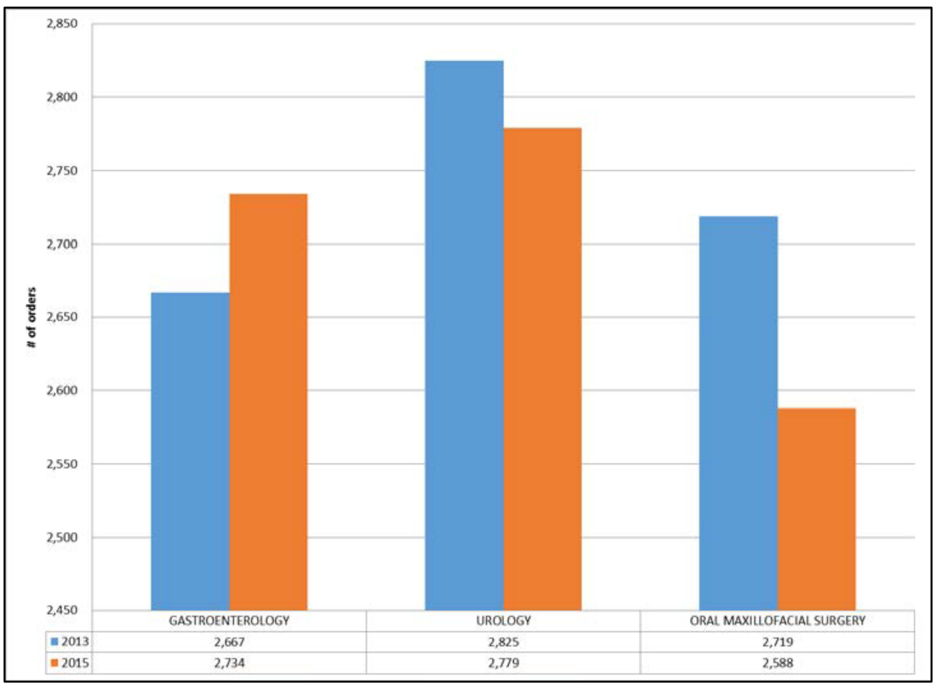



Figure 4. Annual Number of Orders Placed.

By combining both the procurement cost data and the orders placed data, an average cost per order can be obtained, as seen in Table 10. Gastroenterology spent $161.17 per order on average in 2013 and $113.32 in 2015. Urology spent $71.72 per order on average in 2013 and $28.48 in 2015. Oral Maxillofacial Surgery spent $128.59

per order on average in 2013 and $76.10 in 2015. These are similar findings to the procurement cost data. All three customers have a lower cost per order when comparing 2013 to 2015.

Table 10. Average Cost per Order.

| | 2013 | 2015 |
|---|---|---|
| GASTROENTEROLOGY | $ 161.17 | $ 113.32 |
| UROLOGY | $ 71.72 | $ 28.48 |
| ORAL MAXILLOFACIAL SURGERY | $ 155.71 | $ 87.91 |

To improve the data description of order cost, this project has divided the procurement cost by the type of procurements. Three types of procurements make up the total procurement costs for each customer. These include electronic catalog (ECAT), material management (MM), and purchase card (PC). ECAT orders are vendor sourced through Patterson Dental (Patterson Dental, 2016). These items are typically focused on the support of dental treatment, though other medical product lines may find some medical consumable items useful for their practice. In this study, all MM orders are internally sourced through the NMCSD warehouse. MM orders are stocked in bulk in the NMCSD warehouse for same-day fulfillment. The majority of MM orders are sourced by Cardinal Healthcare, the prime medical supply vendor. The NMCSD supply department uses its operating budget to maintain a centralized stock for many NMCSD customers. The Kanban shelving is solely stocked by MM items for these customers. PC supplies are items that are bought by a PC holder directly with the individual vendor. PC items are not in the MM inventory nor offered in ECAT.

In the Figures 5 and 6, all three departments' spending activity is aggregated by purchase type and summarized by fiscal year. ECAT spending was $239,695 in 2013 and $161,486 in 2015. MM spending was $133,735 in 2013 and $213,169 in 2015. PC spending was $682,382 in 2013 and $241,811 in 2015. Additionally, this data is summarized by quantity, as depicted in Figure 8. In 2013, 359 ECAT orders were placed,

and in 2015, 301 orders were placed. In 2013, 6,593 MM orders were placed and in 2015, 7,466 were placed. In 2013, 1,259 PC orders were placed, and in 2015, 334 were placed.

By splitting the procurement cost by procurement type, a clear distinction can be seen. The majority of procurement cost reductions are attributed to the decrease in PC procurements. Two procurement types have cost reductions: ECAT and PC. The sum of these reductions is $518,781. Of this reduction total, $440,571 is attributed to PC procurement cost reductions, or 85% of all reductions. Strangely, the data demonstrates an increase in warehouse stocked items procurement cost (MM), up to $213,169 from $133,735.

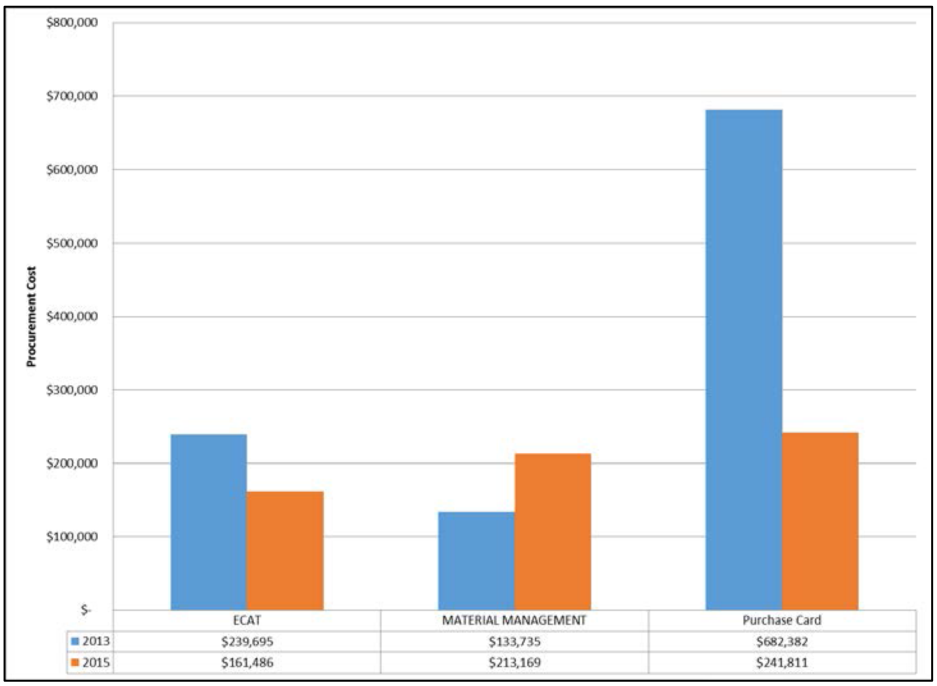



Figure 5. Procurement Cost by Purchase Type.

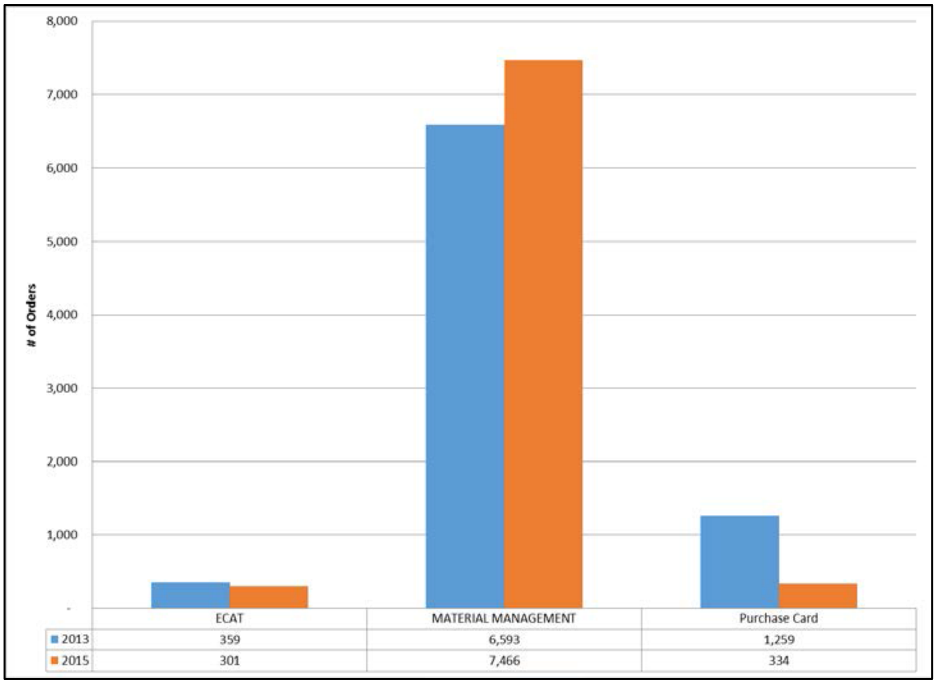



Figure 6. Quantity of Orders by Purchase Type.

By taking the procurement cost and order quantity data, the average cost per order by purchase type can be found, as depicted in Table 11. ECAT procurement cost per order in 2013 was $667.68 and $536.50 in 2015. MM procurement cost per order was $20.28 in 2013 and $28.55 in 2015. PC procurement cost per order was $542 in 2013 and $723.98 in 2015. Similar to the previous trend, the average cost per MM order has increased from $20.28 to $28.55 per order.

Table 11. Procurement Cost per Order Type.

| | 2013 | 2015 |
|---|---|---|
| ECAT | $ 667.68 | $ 536.50 |
| MATERIAL MANAGEMENT | $ 20.28 | $ 28.55 |
| Purchase Card | $ 542.00 | $ 723.98 |

### 2. Monthly Procurement Order Cost and Line Item Quantity

In the previous section, annual data was depicted, which is useful in broad interpretation, but it falls short in a few areas. This section attempts to dig deeper into the

data. With monthly data, trends can be displayed quicker than with annual data, which may help management make appropriate corrections if the data is negatively impacting a business's functions (Keolanui, n.d.). A few examples include the identification of inventory stockouts, (b) seasonal demand fluctuations, and (c) expense reporting. Monthly reporting works well to keep business operations in line with their business plan.

As seen in Figure 7, there is a noticeable downward sloping trend in total procurement cost and PC procurement costs. Due to the scale in this chart, it is difficult to notice a clear decreasing slope in ECAT procurement cost, though this was demonstrated in the earlier figures. It does appear the variation of costs has decreased for ECAT orders, despite the total procurement cost variations. A slightly increasing slope is seen for MM procurement costs. The next few charts mirror Figures 7–10. Each customer is separated out individually.

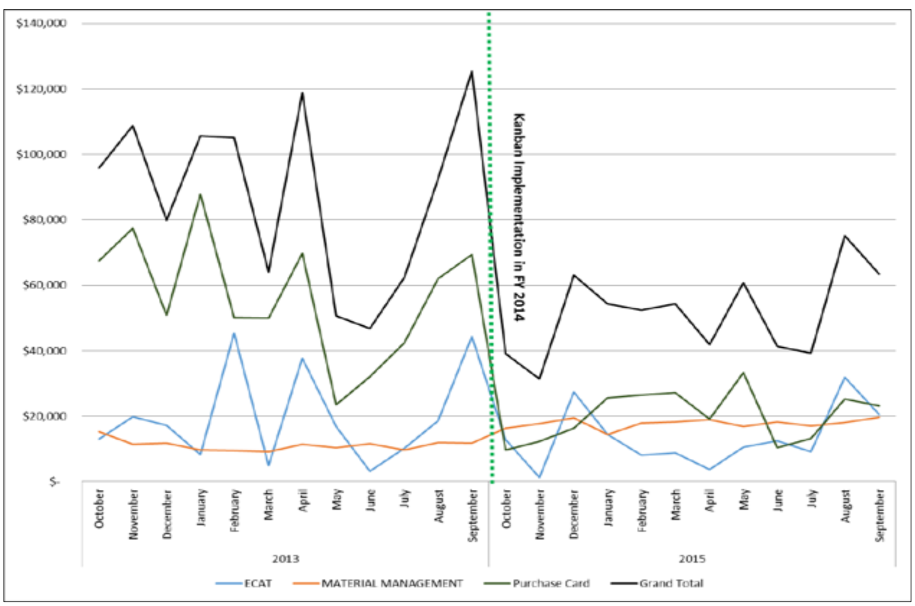



Figure 7. Monthly Procurement Cost (All Three Departments Combined).

In Figure 8, the monthly procurement cost appears to be driven primarily by PC costs. When testing the correlation of these two numbers, a .98 correlation is observed. A slight decreasing total procurement cost and PC cost trend can be observed. MM order

cost slightly increases and ECAT cost remains relatively flat at or near $0. Large procurement order cost variations are observed throughout the period under review.

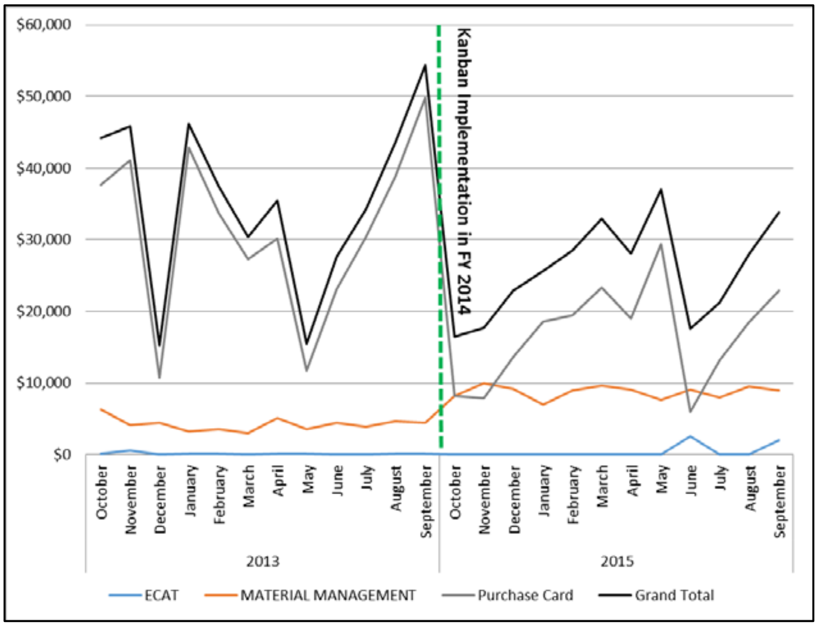



Figure 8. Monthly Procurement Cost—Gastroenterology.

Figure 9 displays a similar data pattern as Figure 8. The Urology department total procurement cost and PC costs are downward sloping. In fact, these two costs are .99 correlated. ECAT procurement cost remains relatively flat at or near $5,000 a month. ECAT procurement costs are nearly zero throughout the periods under review. Larger procurement cost variations are observed in FY 2013. These variations appear to taper down in 2015.

In Figure 10, the majority of all ECAT procurement cost is attributed to the Oral Maxillofacial Surgery (OMFS) department. This should not be a surprise to anyone, as ECAT is the dental source of supply. The prior department had a very strong correlational relationship between PC procurement cost and total procurement costs. For the OMFS department, the strongest cost relation is between ECAT and total procurement cost at .93. PC and total procurement cost have a lower, but still strong, correlation of .76. A downward slope is demonstrated for total, PC, and ECAT

procurements. In addition to the downward trend in costs, a clear reduction in cost variations is demonstrated over time.

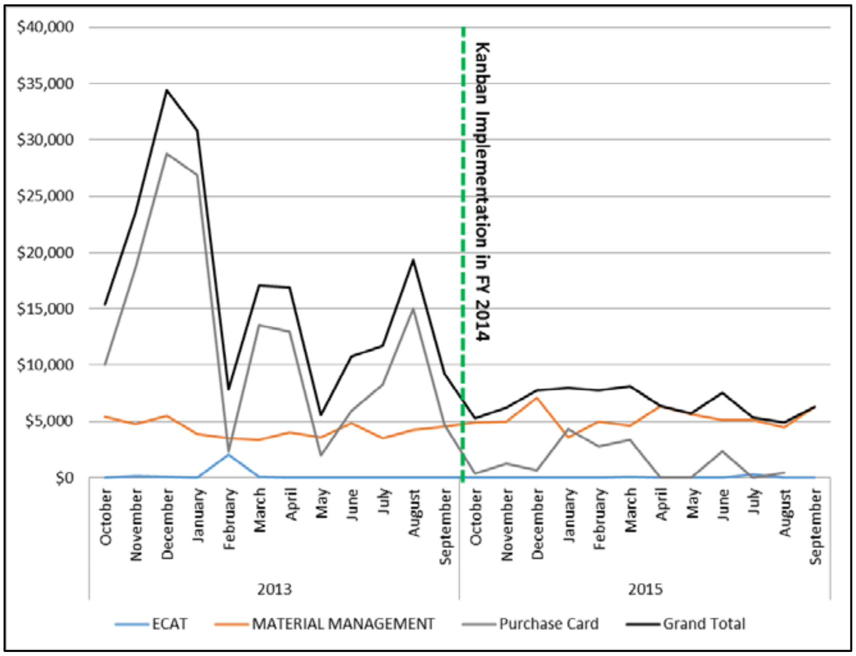



Figure 9. Monthly Procurement Cost—Urology.

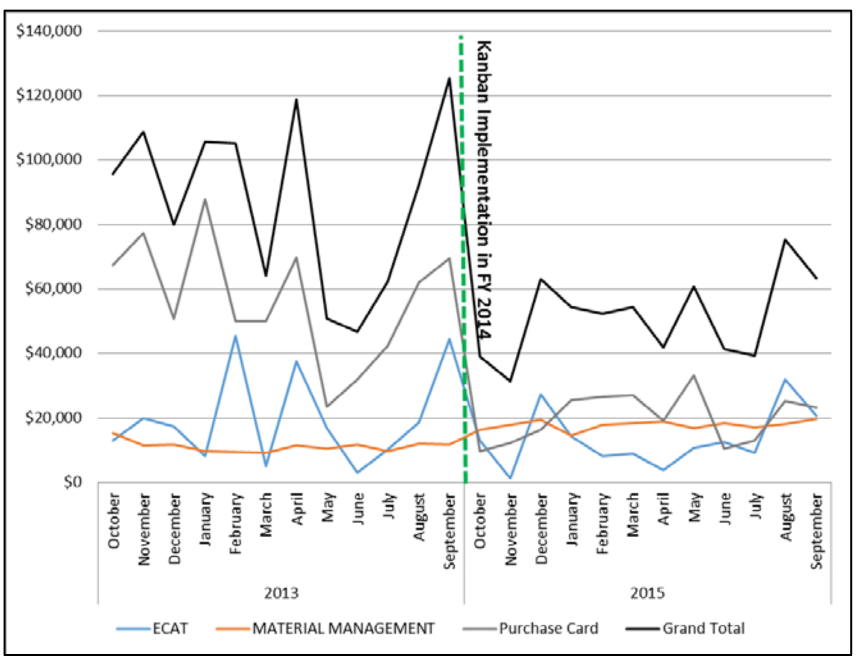
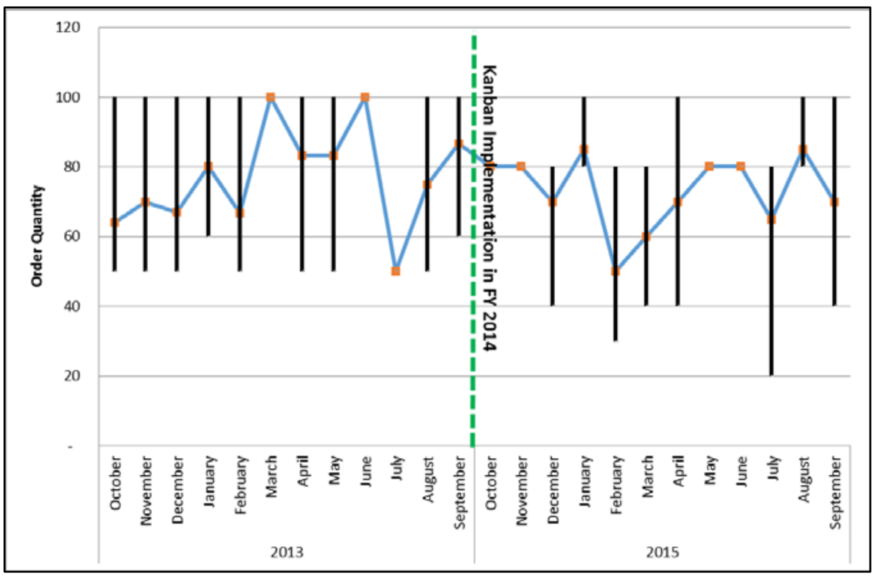



Figure 10. Monthly Procurement Cost—Oral Maxillofacial Surgery.

The following three charts display the minimum order quantity, average order quantity, and maximum order quantity for three sample items over time. The MM item for each department that carried the highest procurement cost over the two-year period of review was selected for review in the following three charts (Figures 11, 12, and 13).

The average order quantity for the Connector Microclave did not change significantly over time (Figure 11). It does appear the order size variation has become inconsistent in FY 2015. Seven of the 12 months in FY 2013 have a minimum order quantity of 50 and a maximum order quantity of 100. Only two months in FY 2015 have a minimum order quantity of 40 and a maximum order quantity of 80. If no vertical line is observed, this equates to only one order or the same order size during this month.

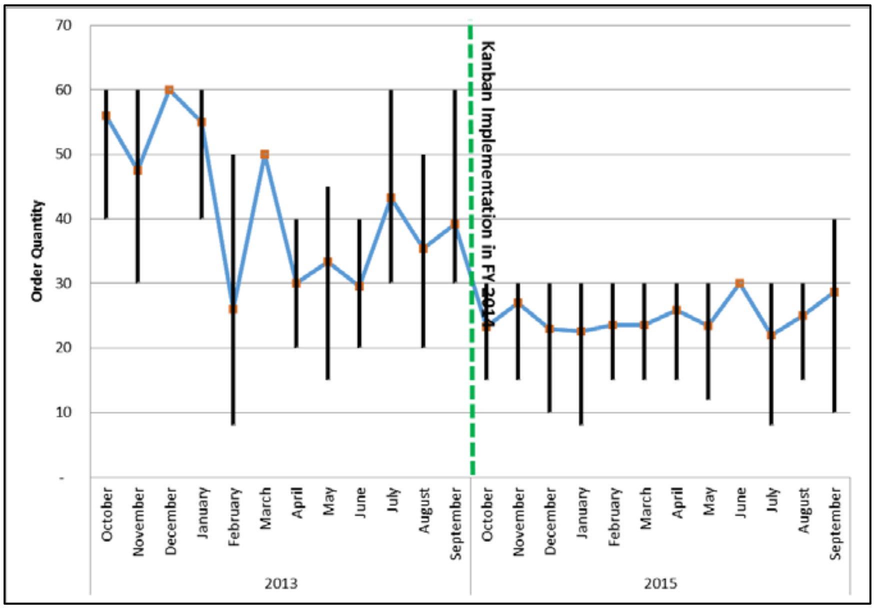



The tops of the vertical bars represent the maximum quantity ordered during the corresponding month. The bottoms of the vertical bars represent the minimum quantity ordered during the corresponding month. The orange plot represents the average order quantity for the corresponding month. The blue line connects the average monthly quantity order to aid in analysis.

Figure 11. Connector Microclave Clear Gastroenterology.

In Figure 12, a clear ordering improvement is observed for the 10 CC Syringe over time. In FY 2013, the average order quantity, order minimum, and order maximum

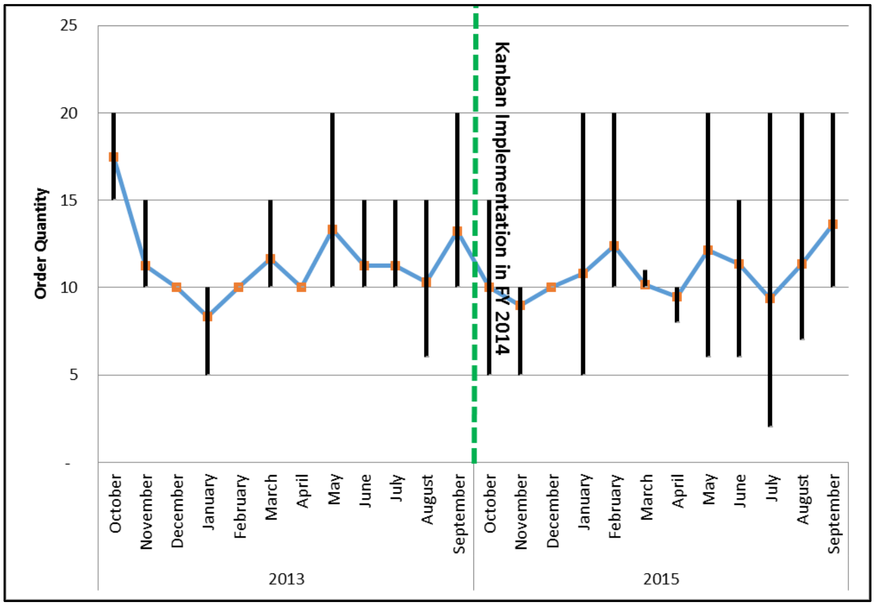
appears to have high variation. In FY 2015, the average order quantity is clearly lower and the order minimum/maximum is very consistent.




The tops of the vertical bars represent the maximum quantity ordered during the corresponding month. The bottoms of the vertical bars represent the minimum quantity ordered during the corresponding month. The orange plot represents the average order quantity for the corresponding month. The blue line connects the average monthly quantity order to aid in analysis.

Figure 12. 10 CC. Syringe Only Luer-Lok T—Urology

In Figure 13, an increased variation in the minimum order quantity and the maximum order quantity is seen in FY 2015. This is contrary to the intent of the two-bin Kanban inventory system. While the highest average order quantity point in this figure lies in FY 2013, it is not clear if any order efficiencies were obtained.

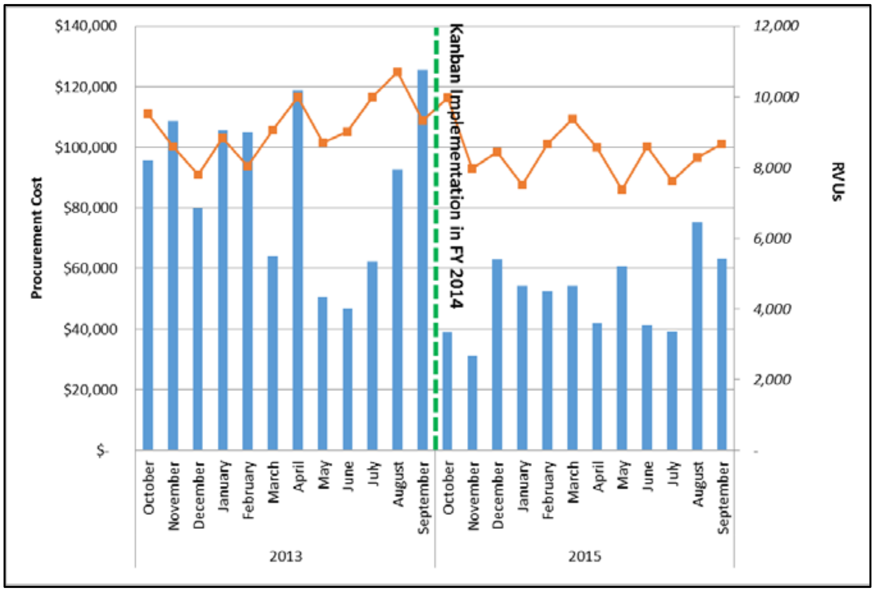



The tops of the vertical bars represent the maximum quantity ordered during the corresponding month. The bottoms of the vertical bars represent the minimum quantity ordered during the corresponding month. The orange plot represents the average order quantity for the corresponding month. The blue line connects the average monthly quantity order to aid in analysis.

Figure 13. Cannula Nasal Divided Adult Curved Tip— Oral Maxillofacial Surgery.

### 3. Procurement Cost Efficiency

As mentioned previously, procurement cost efficiency is the ratio of procurement cost over RVUs. This adds to the procurement cost analysis and answers the question, "how much is NMCSD paying (in terms of procurement cost) per RVU?" In this analysis, the monthly data is shown. In the Figures 14–17, the two data elements are depicted on the same chart for each department under review. Figures 18–21 include the monthly ratio of procurement cost efficiency over time, which was derived from the ratio of the first four charts.

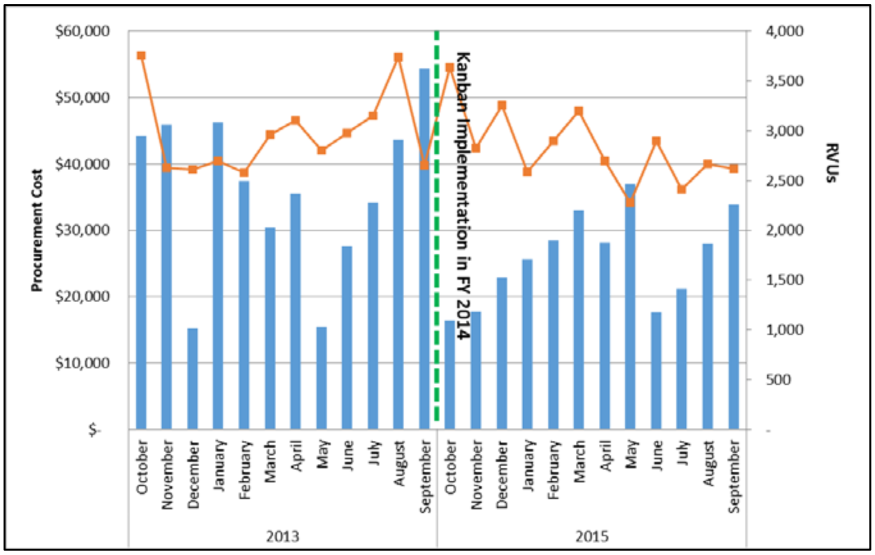



The blue bars reflect the left axis of procurement cost. The orange line reflects the right axis of RVUs.

Figure 14. Monthly Procurement Cost and RVU—
All Three Departments.

The total RVU workload in Figure 14 does appear to trend slightly downward. The procurement cost appears to have a stronger downward slope from FY 2013 to FY 2015. IN FY 2013 there were more than seven months where procurement costs exceeded $80,000. IN FY 2015 every month posts less than $80,000 in procurement costs. The spread of the data in 2013 appears to be much smaller than in FY 2015.

Figure 15 is more difficult to analyze without descriptive statistics, which come later in this chapter. There appears to be a downward sloping procurement cost and RVUs.

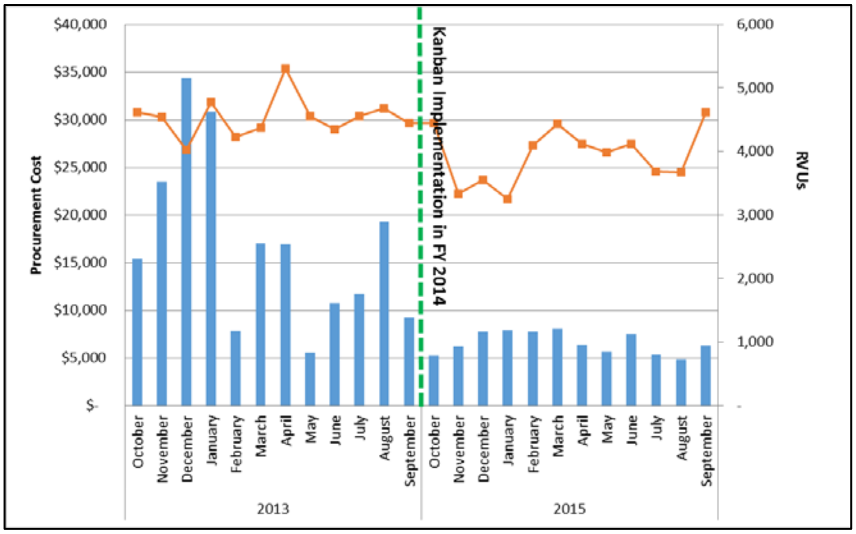



The blue bars reflect the left axis of procurement cost. The orange line reflects the right axis of RVUs.

Figure 15. Monthly Procurement Cost and RVU—Gastroenterology.

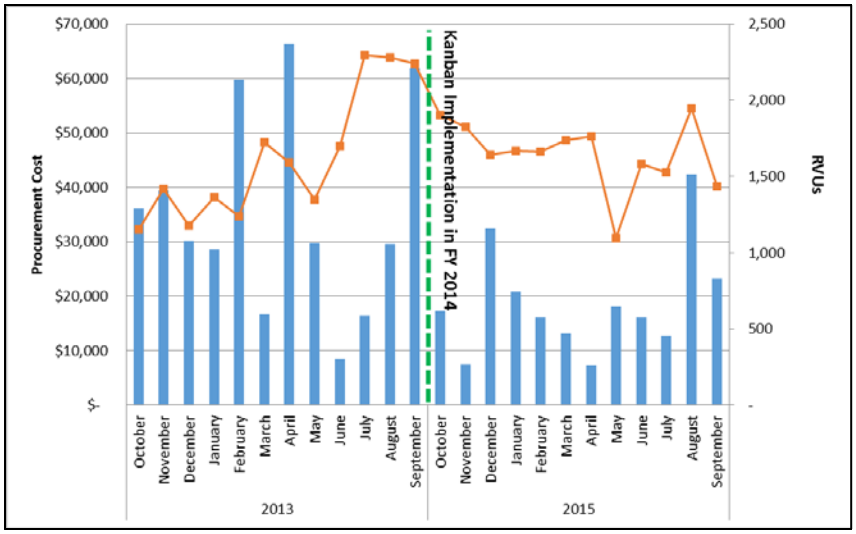
The cost in Figure 16 significantly dropped from FY 2013 to FY 2015. The RVU data appears to slightly trend down as well. The variation in the procurement cost also becomes very consistent in FY 2015. The spread of the minimum and maximum monthly procurement cost in FY 2015 is less than $3,000. In FY 2013, the procurement cost spread is close to $30,000, which is 10 times wider than the FY 2015 spread.

In Figure 17, the three highest points of monthly procurement cost data lies in FY 2013 which are at or above $60,000. The closest monthly procurement cost in 2014 is August which is just over $40,000. There appears to be a downward procurement cost trend from FY 2013 to FY 2015. The RVU data comparison is difficult to ascertain by merely looking. The descriptive statistics portion of this chapter examines this further.



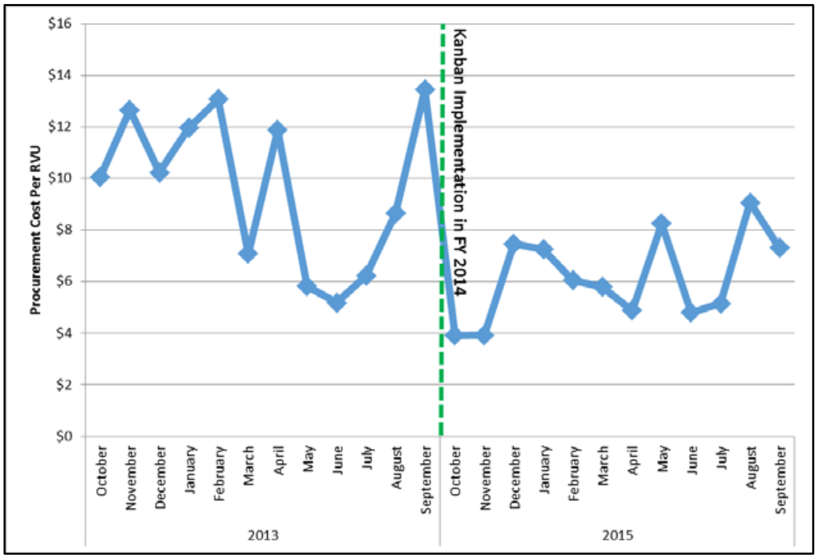

The blue bars reflect the left axis of procurement cost. The orange line reflects the right axis of RVUs.

Figure 16. Monthly Procurement Cost and RVU—Urology.




The blue bars reflect the left axis of procurement cost. The orange line reflects the right axis of RVUs.

Figure 17. Monthly Procurement Cost and RVU—Oral Maxillofacial Surgery.



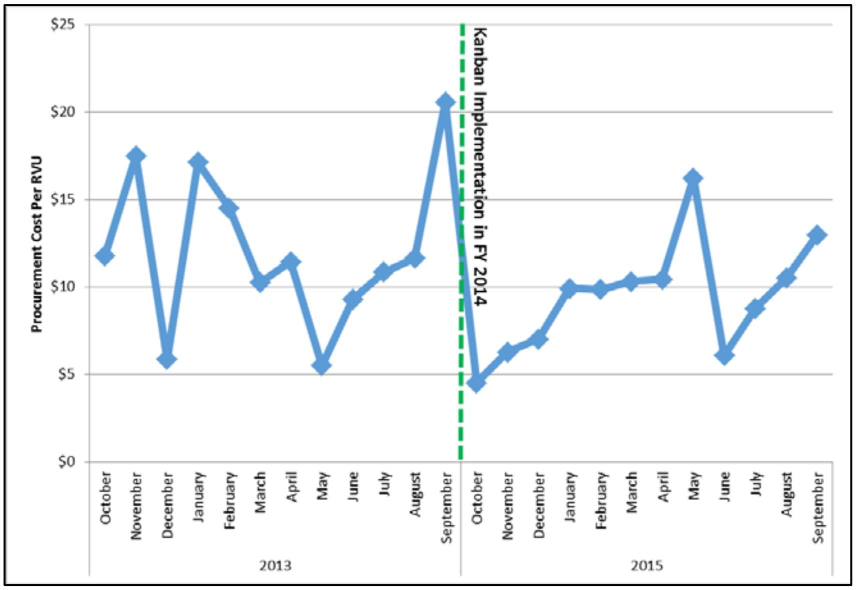

The plots on this chart represent procurement cost divided by RVUs. This measure is referred to cost per RVU.

Figure 18. Procurement Cost per RVU—All Three Departments Combined.

In Figure 18, the shape of the data for all departments combined has a clear downward slope. Seven of the data points in FY 2013 are higher than $10.00 per RVU. These data points are higher than the highest data point in FY 2015 which is less than $10.00 per RVU. Figure 18 displays two data points in FY 2015 that drop below $4.00 procurement cost per RVU.

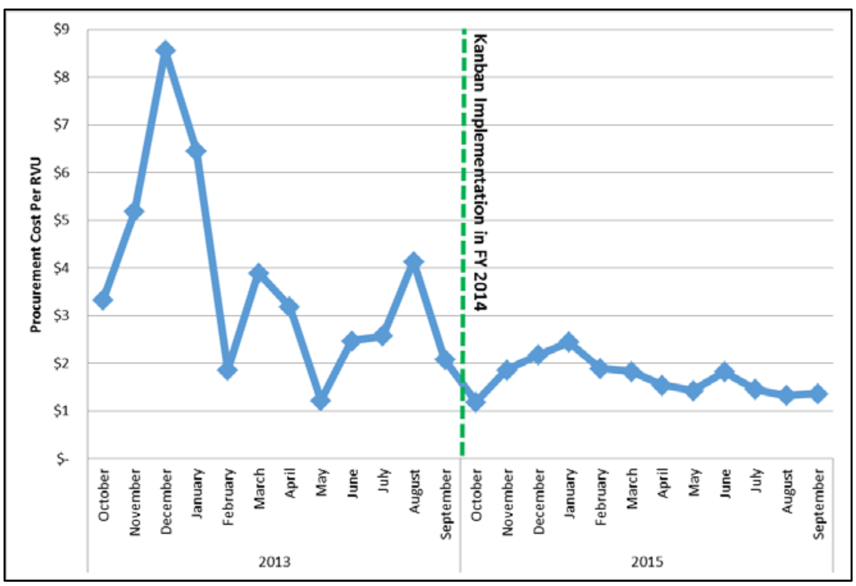
In Figure 19, the highest data point is in September of 2013. In fact, three of the highest data points on this chart are in FY 2013: November, January, and September. The data appears to spread widely in both FYs. A slight downward trend is seen. From January to April in FY 2015, the cost per RVU remained very consistent. For these four consecutive months, the cost per RVU remained around $10.00 per RVU.

Figure 20 shows a steep decline in cost per RVU occurs after three consecutive increases in the beginning of FY 2013. Three clear spikes are observed in FY 2013. In FY 2015, the variation of the data flattens out to under $3.00 per RVU across the entire FY.




The plots on this chart represent procurement cost divided by RVUs. This measure is referred to cost per RVU.

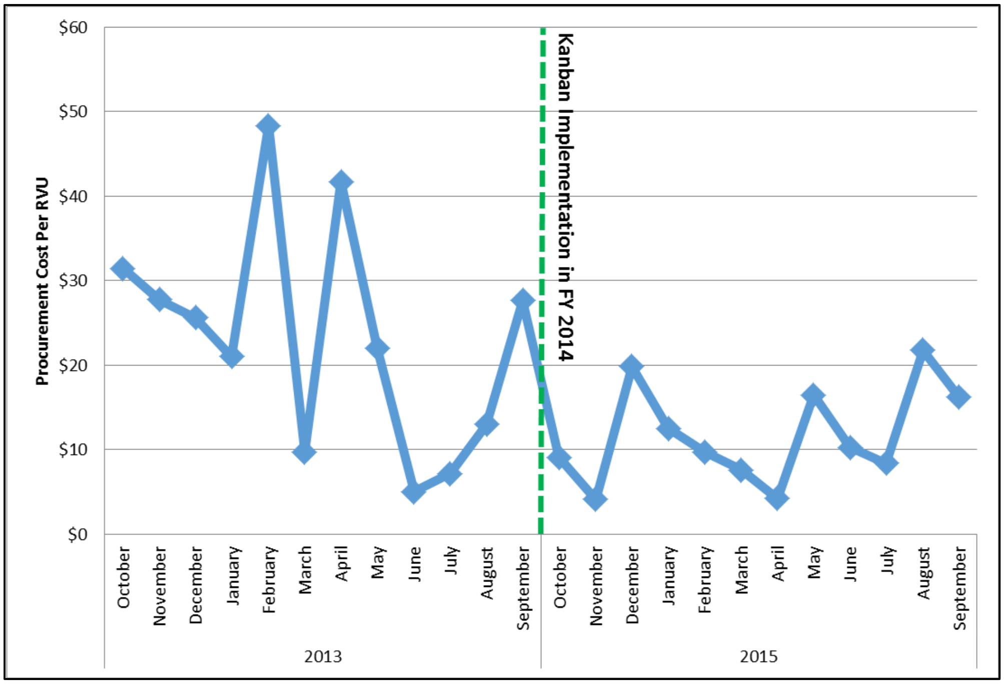
Figure 19. Procurement Cost per RVU—Gastroenterology.




The plots on this chart represent procurement cost divided by RVUs. This measure is referred to cost per RVU.

Figure 20. Procurement Cost per RVU—Urology.

Three spikes of cost per RVU are observed in both FY 2013 and FY 2015 in Figure 21. The spikes in FY 2013 are much higher than the spike in FY 2015. The shape of the data in both sets looks similar, though the downward trend in these FYs is clear.




The plots on this chart represent procurement cost divided by RVUs. This measure is referred to cost per RVU.

Figure 21. Procurement Cost per RVU—Oral Maxillofacial Surgery.

## C. PROCUREMENT COST AND PROCUREMENT EFFICIENCY STATISTICS

The statistical analysis evaluates two research questions: (1) Did the procurement cost change from 2013 to 2015, and (2) Did the procurement efficiency change from 2013 to 2015? These research questions were applied to the three medical departments' cumulative totals as well as to each individual department. In the previous analysis in this chapter, assumptions about the observations were inferred. This was done based on the shape of the data displayed. In this section, concrete claims can be made about the changes under analysis.

The distribution of a data set is one requirement in deciding which statistical analysis tool should be utilized in the analysis (Weiss, 2008). The data sets under review were not normally distributed. Given this, the commonly utilized *t*-test, mean, and standard deviation cannot accurately be used to analyze the data sets (Weiss, 2008). For the sake of timeliness, only one distribution is depicted in Figure 22 for daily order quantity in 2013 in the Gastroenterology department. This distribution is skewed and has variation in excess of a normal distribution. In order to ensure a consistent statistical analysis is performed on all data samples, this project utilizes box and whisker and non-parametric tests to confirm the research questions.

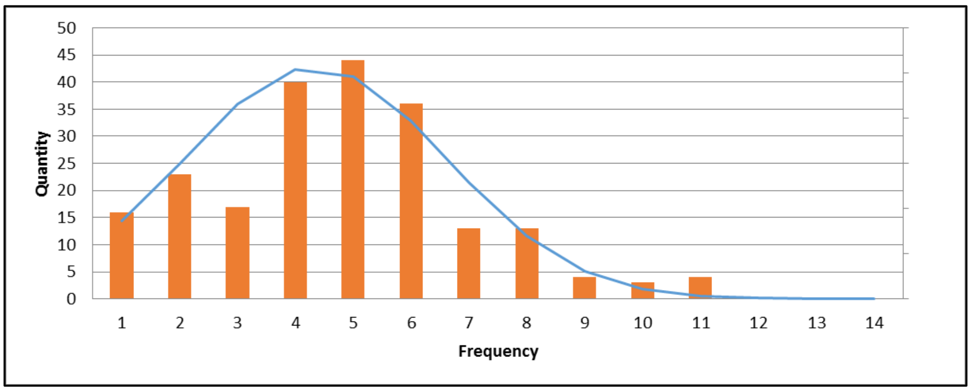



Figure 22. Daily Procurement Quantity Frequency Distribution for 2013—Gastroenterology

### 1. Box and Whisker Plot

In Figure 22, the data distribution is right skewed. When the data distribution is not normal, accurate forecasting is not impossible (Harrington, Hoffherr, & Reid, 1998). However, the use of mean to describe the data set given non-normally distributed data is not appropriate (Harrington, Hoffherr, & Reid, 1998). Measuring standard deviation of a non-normally distributed data set can also be misleading (Harrington, Hoffherr, & Reid, 1998). To accurately compare non-normally distributed data sets, the use of a box and whisker plot is helpful. Box and whisker plots utilize five numbers to describe a data set as shown in Figure 23. "By adding visual representation to a number summary,

perception of the major characteristics of distributions can be greatly facilitated" (Hartwig & Dearling, 1969, p. 14).

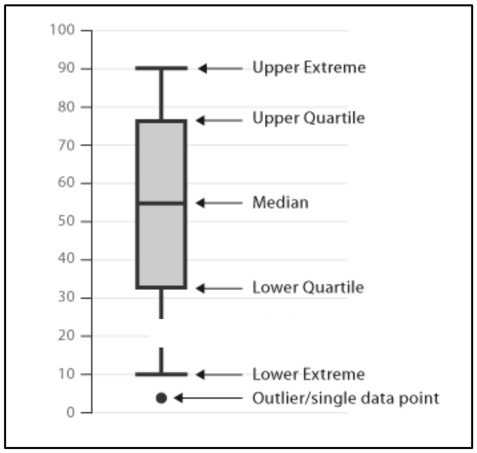



Figure 23. Point Description on a Box and Whisker Plot.

### 2. Test Statistic

Two hypotheses are tested for all three departments cumulatively and each department individually for a total of eight tests.

$$H_o\colon \mu_B - \mu_A = 0$$

$$H_A\colon \mu_B - \mu_A \neq 0$$

In hypothesis one, the monthly sums of the 2013 procurement costs are compared to the monthly sums of 2015 procurement costs. In hypothesis two, the monthly procurement cost per RVU in 2013 is compared to the monthly procurement cost per RVU in 2015. The null hypotheses are rejected if the *p*-values are lower than the established level of significance, or alpha. This project utilizes an alpha of .05. To confirm the *p*-value, the proper test statistic must be selected.

The Wilcoxon is a nonparametric statistical test. It is similar to the two sample *t*-test (Taeger & Kuhnt, 2014). The two sample *t*-test compares means and the Wilcoxon Rank Sums Test compares medians (Weiss, 2008). The *t*-test assumes the sample size is large and normally distributed. In Figure 22, a non-normal distribution is displayed. This

project will compare 12 monthly aggregate data sets, which constitutes a small sample size. Given these dimensions, a two sample *t*-test is inappropriate to compare two data sets (Weiss, 2008). The appropriate test statistics to utilize for smaller and on-normally distributed data sets are non-parametric tests (Weiss, 2008). For this analysis, a Wilcoxon rank sums test is utilized. The Wilcoxon test is appropriate given the data sets compared are symmetric, as in before and after, but not necessarily normally distributed (Weiss, 2008).

The data analysis of the Wilcoxon Rank Sums Test is manually calculated in Microsoft Excel. There is a *t*-test function under the data analysis tab in Microsoft Excel that computes the data to arrive at the *p*-value automatically. There is no specific function in Microsoft Excel to compute *p*-values for the Wilcoxon Rank Sum Test.

The first step in setting up the Wilcoxon test in Microsoft Excel is to rank the ordinal value between all observations in both monthly data sets from smallest to largest (Kullowatz, 2014). The smallest observation is assigned a rank of one and the largest observation is assigned a rank of 24 (Kullowatz, 2014). Table 12 shows a sample of organization and ranking the observations in preparation for the Wilcoxon Rank Sums Test.

Table 12. Sample of Data Preparation for Wilcoxon Analysis in Microsoft Excel.

| | A | B | C | D | E |
|---|---|---|---|---|---|
| 1 | | FY 2013 | FY 2015 | Ranks 1 | Rank 2 |
| 2 | October | $ 3.33 | $ 1.19 | 19 | 1 |
| 3 | November | $ 5.18 | $ 1.86 | 22 | 11 |
| 4 | December | $ 8.56 | $ 2.17 | 24 | 14 |
| 5 | January | $ 6.46 | $ 2.45 | 23 | 15 |
| 6 | February | $ 1.86 | $ 1.89 | 10 | 12 |
| 7 | March | $ 3.89 | $ 1.83 | 20 | 9 |
| 8 | April | $ 3.19 | $ 1.54 | 18 | 7 |
| 9 | May | $ 1.23 | $ 1.43 | 2 | 5 |
| 10 | June | $ 2.47 | $ 1.83 | 16 | 8 |
| 11 | July | $ 2.58 | $ 1.45 | 17 | 6 |
| 12 | August | $ 4.13 | $ 1.32 | 21 | 3 |
| 13 | September | $ 2.08 | $ 1.36 | 13 | 4 |

In Table 12, the "FY 2013" column directly corresponds to the "Ranks 1" column. The "FY 2015" column directly corresponds to the "Rank 2" column. The ranks

are determined by the “rank” function in Excel. Lower cost data is assigned lower scores. In Table 12, Cell D2 is realized with the Excel function =RANK(B2,$B$2:$C$13,1). This means that $3.33 (cell B2) is ranked 19 out of the 24 observations. This rank function is repeated for all cells under the “Ranks 1” and “Ranks 2” columns.

According to Kullowatz, to find the *p*-value, six other variables are needed. These include:

- The number of variables in the first data set (n1)
- The number of variables in the second data set (n2)
- The sum of ranks in the first data set (Sum)
- The expected sum of ranks in each data set (expectation)
- The sampling distribution of the median ranks (Std. error)
- A comparison of the median data with what is expected under the null hypothesis (Stat) (Kullowatz, 2014)

Table 13. Sample of Data Table for Wilcoxon Analysis in Microsoft Excel.

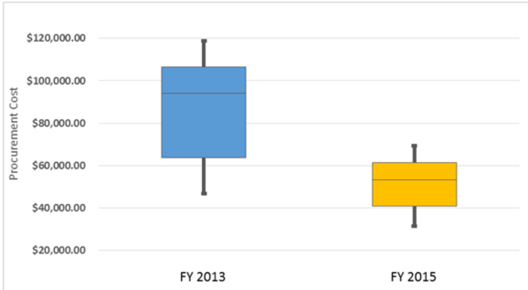
| | A | B | C | D |
|---|---|---|---|---|
| 1 | | | Ranks 1 | Rank 2 |
| 2 | n1= | 12 | 19 | 1 |
| 3 | n2= | 12 | 22 | 11 |
| 4 | Sum= | 205 | 24 | 14 |
| 5 | Expectation | 150 | 23 | 15 |
| 6 | Std. error | 17.3205 | 10 | 12 |
| 7 | Stat= | 3.17543 | 20 | 9 |
| 8 | P-value= | 0.00075 | 18 | 7 |
| 9 | | | 2 | 5 |
| 10 | | | 16 | 8 |
| 11 | | | 17 | 6 |
| 12 | | | 21 | 3 |
| 13 | | | 13 | 4 |

In all the sample sets under review, n1 and n2 are the same. This is the number of variables in each data set that is tested. Since all of the data in both hypotheses are organized by month, both n1 and n2 are always 12. Sum is

computed by adding all the ranks in the "Ranks 1" column. In the sample provided in Table 13, 205 is the sum of all the ranks in the "Ranks 1" column (19+22+24+23+10+20+18+2+16+17+21+13). The expectation is the sum of all the ranks divided by two. In this case, since there are 24 ranks, the expectation is 150 ((1+2+3+4+5+6+7+8+9+10+11+12+13+14+15+16+17+18+19+20+21+22+23+24)/2). This is the expectation for all samples in these Wilcoxon tests, since all samples under review have 24 possible ranks. The Std. error is computed with the following formula in Excel =SQRT(B2*B3*(B2+B3+1)/12). In the case of the sample provided in Table 13, the Std. error is 17.3205. This is also the same Std. error for all samples in this project since it is also based on sample sizes which are all the same in every test. The Stat is the difference between the Sum and the Expectation divided by the Std. Error. For Table 13 data, the Excel formula would be =(B4-B5)/B6 or 3.17543.

With all six variables identified, the *p*-value can be obtained using the standard normal distribution with the Excel formula: = 1 - NORM.S.DIS(X, CUMULATIVE). The "X" in the NORM.S.DIS formula is the Stat number that was derived by taking the difference between sum of ranks and the expectation divided by the Std. error. The mean is assumed to be "0" since this is the expected difference between samples. The std_dev in this formula is assumed to be "1." For the cumulative variable, "1" should be entered, since this formula is a cumulative distribution function and not a probability mass function. Plugging in the correct data, the formula would be as follows: =1-norm.s.dist(B7,1) or .00075. This method is repeated for both hypotheses among all departments and all departments cumulatively for a total of eight Wilcoxon Rank Sum Tests.

Figures 24–27 consolidate the box and whisker plot (upper left corner), box and whisker plot data details (lower right corner), the data table in question (upper right corner), and the Wilcoxon test table for every test conducted (lower right corner). By putting all these charts together the analysis is easily understood.




| | FY 2013 | FY 2015 |
|---|---|---|
| October | $ 95,731.52 | $ 39,038.49 |
| November | $ 108,703.99 | $ 31,367.51 |
| December | $ 79,806.36 | $ 63,065.41 |
| January | $ 105,646.88 | $ 54,387.13 |
| February | $ 105,113.82 | $ 52,441.18 |
| March | $ 64,150.72 | $ 54,277.69 |
| April | $ 118,763.20 | $ 41,880.96 |
| May | $ 50,729.35 | $ 60,755.70 |
| June | $ 46,831.37 | $ 41,340.17 |
| July | $ 62,342.83 | $ 39,317.63 |
| August | $ 92,513.61 | $ 75,216.74 |
| September | $ 125,478.37 | $ 63,376.64 |

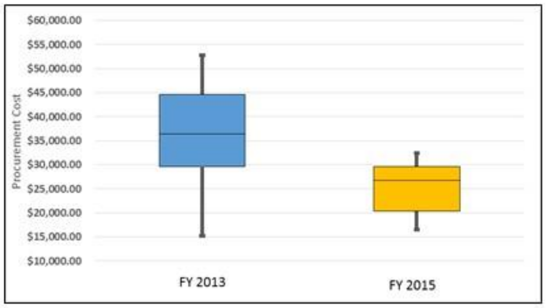
| | 2013 | 2015 |
|---|---|---|
| Minimum | $ 46,831.37 | $31,367.51 |
| Q1 | $ 63,698.75 | $40,834.54 |
| Median | $ 94,122.57 | $53,359.44 |
| Q3 | $106,411.16 | $61,333.13 |
| Max | $125,478.37 | $75,216.74 |

| | | **Ranks 1** | **Ranks 2** |
|---|---|---|---|
| n1= | 12 | 19 | 2 |
| n2= | 12 | 22 | 1 |
| Sum= | 204 | 17 | 13 |
| Expectation | 150 | 21 | 10 |
| Std. error | 17.3205 | 20 | 8 |
| Stat= | 3.1177 | 15 | 9 |
| P-value= | **0.0009** | 23 | 5 |
| | | 7 | 11 |
| | | 6 | 4 |
| | | 12 | 3 |
| | | 18 | 16 |
| | | 24 | 14 |

Figure 24. Cumulative Procurement Cost Analysis.

In Figure 24, clear differences are observed in procurement cost data in the box and whisker plot, the five summary data display, and the Wilcoxon test display. The interquartile range of data in 2013 is $42,712, and in 2015 $29,965.62. Similarly there is a decrease of the median procurement cost in 2013 at $94,122 down to $53,359 in 2015. The data outliers are also smaller in 2015 than that of 2013. These trends are echoed in the Wilcoxon test with the *p*-value of **.0009** which is significantly lower than .05. The sum of ranks in 2013 is 204, which is statically significantly lower than the expected sums of rank of 150.

In Figure 25, similar findings are observed as in Figure 24, with one exception. The interquartile range of data in 2013 is $14,955, and in 2015 is $9,311. Similarly, there is a decrease of the median procurement cost in 2013 at $36,343 down to $26,791 in 2015. The minimum data outlier in 2013 of $15,253 is smaller than the lowest outlier in 2015 of $16,463. These trends are echoed in the Wilcoxon test with the *p*-value of **.0163** which is significantly lower than .05. The sum of ranks in 2013 is 187, which is statically significantly lower than the expected sums of rank of 150. This finding was not as significant as the previous test, but strongly significant overall.



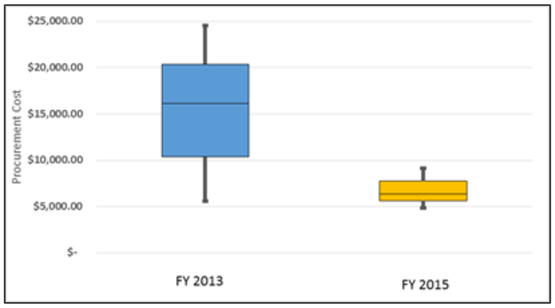

| | FY 2013 | FY 2015 |
|---|---|---|
| October | $ 44,218.88 | $ 16,463.73 |
| November | $ 45,806.04 | $ 17,727.73 |
| December | $ 15,253.17 | $ 22,854.90 |
| January | $ 46,211.56 | $ 25,603.43 |
| February | $ 37,428.98 | $ 28,514.77 |
| March | $ 30,356.22 | $ 32,959.83 |
| April | $ 35,440.85 | $ 28,116.71 |
| May | $ 15,446.42 | $ 36,958.86 |
| June | $ 27,570.07 | $ 17,605.41 |
| July | $ 34,219.40 | $ 21,176.21 |
| August | $ 43,544.62 | $ 27,980.39 |
| September | $ 54,350.98 | $ 33,848.43 |

| | 2013 | 2015 |
|---|---|---|
| Minimum | $ 15,253.17 | $ 16,463.73 |
| Q1 | $ 29,659.68 | $ 20,314.09 |
| Median | $ 36,434.92 | $ 26,791.91 |
| Q3 | $ 44,615.67 | $ 29,626.04 |
| Max | $ 54,350.98 | $ 36,958.86 |

| | | Ranks 1 | Rank 2 |
|---|---|---|---|
| n1= | 12 | 21 | 3 |
| n2= | 12 | 22 | 5 |
| Sum= | 187 | 1 | 7 |
| Expectation | 150 | 23 | 8 |
| Std. error | 17.3205 | 19 | 12 |
| Stat= | 2.1362 | 13 | 14 |
| P-value= | **0.0163** | 17 | 11 |
| | | 2 | 18 |
| | | 9 | 4 |
| | | 16 | 6 |
| | | 20 | 10 |
| | | 24 | 15 |

Figure 25. Gastroenterology Procurement Cost Analysis.

In Figure 26, similar findings are observed as in Figure 25. The interquartile range of data in 2013 is $10,001 and in 2015 is $2,115. This is a massive reduction in variation, which was observed in Figures 16 and 20. The median procurement cost in 2013 for the Urology department was $16,165. The median procurement cost decreased to $6,327 in 2015. The rank sums for 2013 was 211, which is the largest of sums and is much higher than the hypothesized 150. This difference results in a *p*-value of **.0002.** This is the third test in a row that rejects the null hypothesis for procurement cost differences.

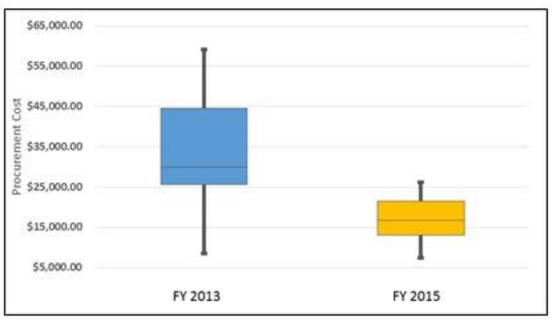



| | FY 2013 | FY 2015 |
|---|---|---|
| October | $ 15,392.99 | $ 5,291.98 |
| November | $ 23,521.77 | $ 6,199.25 |
| December | $ 34,395.93 | $ 7,721.27 |
| January | $ 30,808.26 | $ 7,954.55 |
| February | $ 7,852.82 | $ 7,757.67 |
| March | $ 17,055.69 | $ 8,123.09 |
| April | $ 16,938.04 | $ 6,353.10 |
| May | $ 5,591.55 | $ 5,699.72 |
| June | $ 10,739.71 | $ 7,518.97 |
| July | $ 11,743.24 | $ 5,360.74 |
| August | $ 19,315.06 | $ 4,872.16 |
| September | $ 9,242.24 | $ 6,302.60 |

| | 2013 | 2015 |
|---|---|---|
| Minimum | $ 5,591.55 | $ 4,872.16 |
| Q1 | $ 10,365.34 | $ 5,614.98 |
| Median | $ 16,165.52 | $ 6,327.85 |
| Q3 | $ 20,366.74 | $ 7,730.37 |
| Max | $ 34,395.93 | $ 8,123.09 |

| | | Ranks 1 | Rank 2 |
|---|---|---|---|
| n1= | 12 | 18 | 2 |
| n2= | 12 | 22 | 6 |
| Sum= | 211 | 24 | 10 |
| Expectation | 150 | 23 | 13 |
| Std. error | 17.3205 | 12 | 11 |
| Stat= | 3.5218 | 20 | 14 |
| P-value= | **0.0002** | 19 | 8 |
| | | 4 | 5 |
| | | 16 | 9 |
| | | 17 | 3 |
| | | 21 | 1 |
| | | 15 | 7 |

Figure 26. Urology Procurement Cost Analysis.




| | FY 2013 | FY 2015 |
|---|---|---|
| October | $ 36,119.65 | $ 17,282.78 |
| November | $ 39,376.18 | $ 7,440.53 |
| December | $ 30,157.26 | $ 32,489.24 |
| January | $ 28,627.06 | $ 20,829.15 |
| February | $ 59,832.02 | $ 16,168.74 |
| March | $ 16,738.81 | $ 13,194.77 |
| April | $ 66,384.31 | $ 7,411.15 |
| May | $ 29,691.38 | $ 18,097.12 |
| June | $ 8,521.59 | $ 16,215.79 |
| July | $ 16,380.19 | $ 12,780.68 |
| August | $ 29,653.93 | $ 42,364.19 |
| September | $ 61,885.15 | $ 23,225.61 |

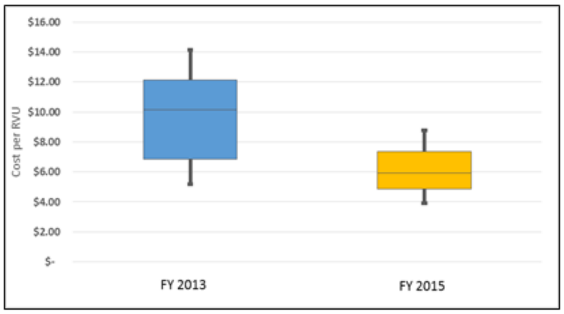
| | 2013 | 2015 |
|---|---|---|
| Minimum | $ 8,521.59 | $ 7,411.15 |
| Q1 | $ 25,655.00 | $13,091.25 |
| Median | $ 29,924.32 | $16,749.29 |
| Q3 | $ 44,490.14 | $21,428.27 |
| Max | $ 66,384.31 | $42,364.19 |

| | | Ranks 1 | Rank 2 |
|---|---|---|---|
| n1= | 12 | 19 | 10 |
| n2= | 12 | 20 | 2 |
| Sum= | 190 | 17 | 18 |
| Expectation | 150 | 14 | 12 |
| Std. error | 17.3205 | 22 | 6 |
| Stat= | 2.3094 | 9 | 5 |
| P-value= | **0.0105** | 24 | 1 |
| | | 16 | 11 |
| | | 3 | 7 |
| | | 8 | 4 |
| | | 15 | 21 |
| | | 23 | 13 |

Figure 27. OMFS Procurement Cost Analysis.

In Figure 27, the data displays the procurement cost data for OMFS. In 2013, the interquartile range was $18,835 and in 2015 is dropped to $8,337. The maximum outlier is drastically different in FY 2013. The median procurement cost of 2013 was $29,924.

The median procurement cost in FY 2015 dropped to $16,749. The total sum of the ranks in 2013 is 190. This resulted in a *p*-value of **.0105**. This test rejects the null hypothesis that the procurement cost is equal across FYs.



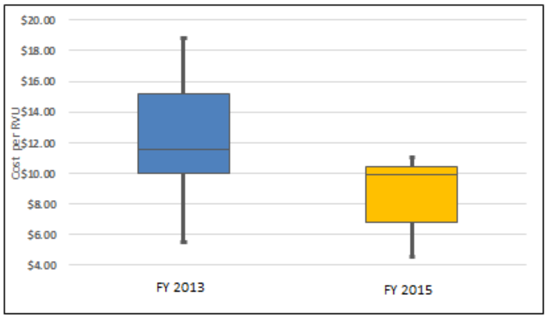

| | FY 2013 | FY 2015 |
|---|---|---|
| October | $ 10.06 | $ 3.91 |
| November | $ 12.66 | $ 3.93 |
| December | $ 10.23 | $ 7.47 |
| January | $ 11.96 | $ 7.25 |
| February | $ 13.07 | $ 6.06 |
| March | $ 7.08 | $ 5.80 |
| April | $ 11.87 | $ 4.88 |
| May | $ 5.82 | $ 8.25 |
| June | $ 5.19 | $ 4.81 |
| July | $ 6.23 | $ 5.15 |
| August | $ 8.65 | $ 9.07 |
| September | $ 13.45 | $ 7.32 |

| | | Ranks 1 | Rank 2 |
|---|---|---|---|
| n1 = | 12 | 18 | 1 |
| n2= | 12 | 22 | 2 |
| Sum= | 198 | 19 | 14 |
| Expectation | 150 | 21 | 12 |
| Std. error | 17.3205 | 23 | 9 |
| Stat= | 2.7713 | 11 | 7 |
| P-value= | **0.0028** | 20 | 4 |
| | | 8 | 15 |
| | | 6 | 3 |
| | | 10 | 5 |
| | | 16 | 17 |
| | | 24 | 13 |

| | 2013 | 2015 |
|---|---|---|
| Minimum | $ 5.19 | $ 3.91 |
| Q1 | $ 6.87 | $ 4.86 |
| Median | $ 10.15 | $ 5.93 |
| Q3 | $ 12.14 | $ 7.35 |
| Max | $ 13.45 | $ 9.07 |

Figure 28. Cumulative Procurement Cost per RVU.

Figure 28 is the beginning of the second hypothesis test that procurement cost per RVU is the same across both FYs. The FY 2013 box and whisker box is much larger with an interquartile range of $5.27. In FY 2015, this interquartile range dropped to $2.49. The median difference is similar as well. In FY 2013, the median procurement cost per RVU was $10.15, which dropped to $5.93 in FY 2015. The sum of ranks is 198, which resulted in a *p*-value of **.0028**.




| | 2013 | 2015 |
|---|---|---|
| Minimum | $ 5.51 | $ 4.53 |
| Q1 | $ 10.01 | $ 6.83 |
| Median | $ 11.55 | $ 9.89 |
| Q3 | $ 15.17 | $ 10.45 |
| Max | $ 20.55 | $ 16.23 |

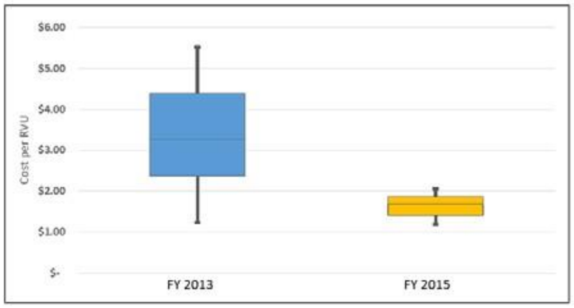
| | FY 2013 | FY 2015 |
|---|---|---|
| October | $ 11.79 | $ 4.53 |
| November | $ 17.48 | $ 6.28 |
| December | $ 5.86 | $ 7.02 |
| January | $ 17.12 | $ 9.92 |
| February | $ 14.52 | $ 9.85 |
| March | $ 10.25 | $ 10.31 |
| April | $ 11.44 | $ 10.44 |
| May | $ 5.51 | $ 16.23 |
| June | $ 9.27 | $ 6.08 |
| July | $ 10.87 | $ 8.79 |
| August | $ 11.65 | $ 10.50 |
| September | $ 20.55 | $ 12.95 |

| | | Ranks 1 | Rank 2 |
|---|---|---|---|
| n1 = | 12 | 18 | 1 |
| n2 = | 12 | 23 | 5 |
| Sum= | 179 | 3 | 6 |
| Expectation | 150 | 22 | 10 |
| Std. error | 17.3205 | 20 | 9 |
| Stat= | 1.6743 | 11 | 12 |
| P-value= | **0.0470** | 16 | 13 |
| | | 2 | 21 |
| | | 8 | 4 |
| | | 15 | 7 |
| | | 17 | 14 |
| | | 24 | 19 |

Figure 29. Gastroenterology Procurement Cost per RVU.

The Gastroenterology procurement cost per RVU is displayed in Figure 29. The differences in the interquartile range are not as drastic as in previous figures. In FY 2013, the range is $5.16 which dropped to $3.62 in FY 2015. This range is the closest interquartile range in all eight figure comparisons in the testing sample. The medians are also closer than that of other samples with a median procurement cost per RVU in FY 2013 of $11.55 and $9.89 in FY 2015. The sum of ranks is 179 which results in the *p*-value of **.0470**. In line with all other tests to this point, the null hypothesis is rejected.

Urology procurement cost per RVU is observed in Figure 30. A drastic difference in the samples is observed: The box and whisker plot for the FY 2015 data is nearly flat. The interquartile range in FY 2013 was $2.02 which dropped to $0.46 in FY 2015, which is eight times smaller. The median procurement cost per RVU dropped from $3.26 in FY 2013 to $1.68 in FY 2015. The rank of sums for this non-parametric test is 205, which resulted in a *p*-value of **.0007**.

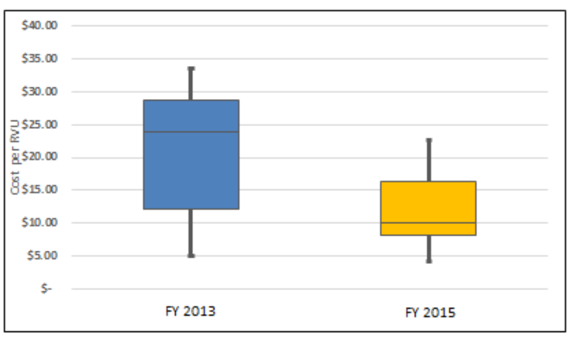



| | FY 2013 | FY 2015 |
|---|---|---|
| October | $ 3.33 | $ 1.19 |
| November | $ 5.18 | $ 1.86 |
| December | $ 8.56 | $ 2.17 |
| January | $ 6.46 | $ 2.45 |
| February | $ 1.86 | $ 1.89 |
| March | $ 3.89 | $ 1.83 |
| April | $ 3.19 | $ 1.54 |
| May | $ 1.23 | $ 1.43 |
| June | $ 2.47 | $ 1.83 |
| July | $ 2.58 | $ 1.45 |
| August | $ 4.13 | $ 1.32 |
| September | $ 2.08 | $ 1.36 |

| | 2013 | 2015 |
|---|---|---|
| Minimum | $ 1.23 | $ 1.19 |
| Q1 | $ 2.37 | $ 1.41 |
| Median | $ 3.26 | $ 1.68 |
| Q3 | $ 4.39 | $ 1.87 |
| Max | $ 8.56 | $ 2.45 |

| | | Ranks 1 | Rank 2 |
|---|---|---|---|
| n1= | 12 | 19 | 1 |
| n2= | 12 | 22 | 11 |
| Sum= | 205 | 24 | 14 |
| Expectation | 150 | 23 | 15 |
| Std. error | 17.3205 | 10 | 12 |
| Stat= | 3.1754 | 20 | 9 |
| P-value= | **0.0007** | 18 | 7 |
| | | 2 | 5 |
| | | 16 | 8 |
| | | 17 | 6 |
| | | 21 | 3 |
| | | 13 | 4 |

Figure 30. Urology Procurement Cost per RVU.




| | FY 2013 | FY 2015 |
|---|---|---|
| October | $ 31.43 | $ 9.09 |
| November | $ 27.71 | $ 4.08 |
| December | $ 25.62 | $ 19.81 |
| January | $ 21.00 | $ 12.48 |
| February | $ 48.34 | $ 9.73 |
| March | $ 9.72 | $ 7.59 |
| April | $ 41.67 | $ 4.21 |
| May | $ 22.01 | $ 16.48 |
| June | $ 5.01 | $ 10.25 |
| July | $ 7.13 | $ 8.37 |
| August | $ 13.00 | $ 21.75 |
| September | $ 27.64 | $ 16.20 |

| | 2013 | 2015 |
|---|---|---|
| Minimum | $ 5.01 | $ 4.08 |
| Q1 | $ 12.18 | $ 8.17 |
| Median | $ 23.81 | $ 9.99 |
| Q3 | $ 28.64 | $ 16.27 |
| Max | $ 48.34 | $ 21.75 |

| | | Ranks 1 | Rank 2 |
|---|---|---|---|
| n1 = | 12 | 22 | 7 |
| n2 = | 12 | 21 | 1 |
| Sum= | 190 | 19 | 15 |
| Expectation | 150 | 16 | 11 |
| Std. error | 17.3205 | 24 | 9 |
| Stat= | 2.3094 | 8 | 5 |
| P-value= | **0.0105** | 23 | 2 |
| | | 18 | 14 |
| | | 3 | 10 |
| | | 4 | 6 |
| | | 12 | 17 |
| | | 20 | 13 |

Figure 31. OMFS Procurement Cost per RVU.

The last of the eight non-parametric tests is in Figure 31 with procurement cost per RVU data for the OMFS department. The interquartile range in FY 2013 is \$16.46, which is cut in half in FY 2015 with an interquartile range of \$8.10. Not only did the range of data decrease over time, but the median of the data also decreased. In FY 2015, median procurement cost per RVU was \$23.81, which substantially dropped to \$9.99 in FY 2015. The sum of ranks was 190, which resulted in a *p*-value of **.0105**.

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# V. CONCLUSION

Kanban has been successful in healthcare and other industries to optimize the supply chain. Kanban simplifies the reordering and stocking of medical supplies for clinical staff. The two-bin system requires that products be divided into two bins equally. As one bin is emptied, the supply technician orders the quantity of that bin. At NMCSD this replenishment is triggered with bar code readers that are subsequently synced into DMLSS for fulfillment. It is expected that this system optimization should reduce inventory sizes, increase inventory turnover, decrease holding cost and decrease ordering costs.

## A. FINDINGS

The data analyzed in this research suggest reductions in both procurement order costs and procurement order cost per RVU. All Wilcoxon tests displayed statistical significance in support of these claims when comparing 2013 and 2015. Specifically, Figures 24–31 show the statistical evidence to support these claims, illustrated with the cost reduction in table 14.

Table 14. Summary findings of monthly medians

| | Procurement Cost | | Procurement Cost per RVU | |
|---|---|---|---|---|
| Department | Before | After | Before | After |
| Gastroenterology | $ 36,434.92 | $ 26,791.91 | $ 11.55 | $ 9.89 |
| Urology | $ 16,165.52 | $ 6,327.85 | $ 3.26 | $ 1.68 |
| OMFS | $ 29,924.32 | $ 16,749.29 | $ 23.81 | $ 9.99 |
| TOTAL | $ 94,122.00 | $ 53,359.00 | $ 10.15 | $ 5.93 |

Trends of these reductions are observed in the aggregate data in Figures 3–10 and in Figures 14–21. Of particular note are Figures 11–13. These three items are the most costly Kanban items for each department. Of these items, only the 10 CC syringe in Urology department displayed a clear reduction in usage and smoothing of ordering

patterns from 2013–2015. The connector microclave for Gastroenterology and the nasal cannula for OMFS showed no usage reduction or smoothing of ordering patterns.

As demonstrated in Figure 5, ~85% of all procurement cost reductions are from the reduction in PC costs. The reduction in PC procurement cost has a large impact on the procurement cost efficiency ratio as well. For several years now, Navy Medicine has tracked PC usage for every MTF. There has been continued and varied PC reduction efforts at the BUMED, regional and MTF for many years, prior to the Kanban implementation.

Nonetheless, the procurement quantity data was not conclusive in assessing the benefits the two-bin Kanban had on two of the three most costly items for the departments under review. PC reduction efforts have been extensive and on-going for several years. Consequently, this research is unable to confirm a direct connection between the procurement cost reduction and procurement cost per RVU with the implementation of Kanban two-bin inventory system. While all null hypotheses are rejected, the research is unable to confirm causation of the two-bin Kanban system. However, it is clear that cost reductions did occur.

## B. LIMITATIONS AND FUTURE WORK

There are a few factors that impacted the scope of this thesis. The resources required to pull data reports needed for comprehensive analysis was limited. The Navy Medicine staff were very accommodating to support this research. The amount of time required to pull the three reports needed per department took a considerable amount of time, in which the staff had to assist outside of their currently assigned duties. This research clearly observes procurement cost and procurement cost per RVU for Gastroenterology, Urology, and OMFS departments at NMCSD. This research also combines these three departments to assess the total procurement cost and procurement cost per RVU observations over time. The combination of these three departments does not mean these cost changes occurred for all of NMCSD. The data only supports changes for the departments under review.

This research focused on the procurement cost and not necessarily at the item activity level, though this was done on three items. The literature has suggested other impacts the two-bin Kanban not tested in this research. This includes decreasing inventory levels, failed orders, reduction of spoilage, reduction of the bullwhip effect, and human capital time saving at the clinical level. These are all key elements that would aide in defining the success of the two-bin Kanban system. Given the time and resource constraints in this project, these approaches were not followed. Inventory impacts, spoilage, bull whip changes, and failed order would be an impactful follow-on study.

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